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INTERNATIONAL HEALTH COMMISSION

EFFECTS OF HOOKWORM DISEASE ON THE MENTAL AND PHYSICAL DEVELOPMENT OF CHILDREN

BY

EDWARD K. STRONG, JR., PH. D.

NEW YORK
THE ROCKEFELLER FOUNDATION
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ORIGIN AND PURPOSE OF THE INVESTIGATION

Long before the work for the relief and control of hookworm disease in the Southern states, it was a matter of common knowledge to persons familiar with the subject that among the effects of the disease was to be included retardation in the mental and physical development of children. During the campaign many extreme cases of dwarfing were attributed to this cause, and many school teachers regarded it as a chief factor in the backwardness of certain children in the grades. This general belief was borne out also by a large number of reported cases whose records showed phenomenal gains in weight, in physical vitality and in mental alertness and achievement. But there had been no extended publication of systematic scientific investigation on groups of children carried out under controlled conditions.

In 1912 the Rockefeller Sanitary Commission and the United States Public Health Service undertook to make such an investigation with a view to securing detailed information on the subject. The Commission made available the necessary funds for the studies on mentality, and for certain of the physical studies for which funds were not at the time available otherwise, and engaged Dr. Edward K. Strong, Jr., then of Columbia University and now of the George Peabody College for Teachers, to carry out the mental tests. Dr. C. W. Stiles, Professor of Zoology of the United States Public Health Service and Scientific Secretary of the Rockefeller Sanitary Commission, arranged to make the physical examination of the children and to administer the necessary treatment; and, through the co-operation of the North Carolina State Board of Education, the Atlantic Coast Line Railway placed at the disposal of the investigators a special car to be used for laboratory and hospital purposes. In the original plan the physical examination was regarded as subsidiary to, though basic for, the mental tests. In carrying it out Dr. Stiles developed an elaborate system of physical tests which in the end proved to be quite as interesting and valuable as the mental tests.

The report here presented contains the results of the mental studies and a partial account of the physical tests. Dr. Stiles and his colleagues will publish in separate articles the physical, clinical and zoological studies which they conducted upon these children. He concurs in the present Summary (p. 7), and the health data given in the present report are based upon details to be found in Dr. Stiles' manuscript.

WICKLIFFE ROSE.

SUMMARY

Mental and physical tests were made upon 115 children in a hookworm-infected county, in order to determine, if possible, what differences exist between non-infected children, infected children who are not treated, and infected children before and after treatment.

The children were divided into five groups according to whether (1) they were not infected (Group A), (2) they were infected but not treated (Group B), (3) they were infected and later cured (Group C), (4) they were infected and treated but not completely cured (Group D), or (5) they were infected and treated but the final condition of their infection could not be determined (Group E).

Physical tests.—When the five group ratings were determined for each of the 186 physical and physiological characters considered, relative markings were given to the groups, on a score system somewhat similar to the score system used in intercollegiate athletic contests. The total number of score points was 5,580, and the theoretical maximum score any group could possibly obtain was 1,860 points. The following results were obtained:

The *uninfected* children (Group A) scored first place in the competition with 1,485 points (80%

of theoretical maximum) in the earlier examination; in the last examination this group fell to second place with 1,290 points (69% of theoretical maximum).

The *infected* children who were *untreated* (Group B) won third place with 1,098 points (59% of theoretical maximum) in the first test; in the last test they fell to fifth place with 847 points (46% of theoretical maximum).

The *infected* children who were *completely cured* (Group C) won second place with 1,242 points (67% of theoretical maximum) in the test conducted before treatment; in the last test, conducted after treatment, during which an average of 40.2 hookworms was collected, they advanced to first place with 1,366 points (73% of theoretical maximum); thus this group actually surpassed the uninfected group (A) by 4%.

The *infected* children who were treated but who upon final microscopic examination were found to be *incompletely cured* (Group D) won fifth place with 823 points (44% of theoretical maximum); during treatment an average of 93.4 hookworms per patient was collected from this group, which then, on the final test, advanced to fourth place with 984 points (53% of theoretical maximum).

A group of *infected* children (Group E) was treated; an average of 100.2 hookworms per patient was collected, but it was impossible to determine whether all the worms were expelled. This group won fourth place with 932 points (50% of theoretical maximum) before treatment; it advanced to third place with 1,093 points (59% of theoretical maximum) after treatment.

The five groups may be conceived of as representing five communities that are competing for 5,580 units of value. All hookworm communities advanced their receipts after they were treated (C, D, E), and one of these (C) actually outstripped another community (A) in which hookworm infection was not originally found; but when left untreated, one hookworm community (B) fell backward in the results of competition. Broadly speaking, the statistics given may be taken as a comparative indication of the physical efficiency of the five communities.

In physical improvement many changes were noticed, but it was particularly the circulatory and the respiratory systems in which treatment resulted in striking favorable changes. Other improvements were in height, weight, lung capacity, complexion, texture of hair, condition of digestion, etc.

Conclusion.—Our figures show, then, *that hookworm disease interferes with physical development. Treatment alleviates this condition to a considerable extent. Apparently young children can regain most of the physical conditions, if not* *all, which they have lost due to the infection.* But the data do also very strongly suggest that the severer the infection and the longer it persists, the less likely it is that the child will ever reach his normal physical development.*

Mental tests.—The mental tests were conducted by men who were not connected with the physical tests nor with the arrangement of the children into the several groups, *i. e.*, A to E. The psychologists had no definite knowledge of the physical or microscopic records either before or after treatment, or of which children were treated and which were left untreated, or which were cured or partially cured. Thus the mental examinations are to be accepted as uninfluenced in any way by the physical or medical findings.

The mental tests show that the group of normal (uninfected) children (Group A) occupied first place in mental advancement from the first to the last tests. If this improvement for Group A be taken as 100%, the improvement in the other groups may be expressed in the following figures:

---

* Dr. Stiles wishes the matter of *degree of infection* and *duration of infection* emphasized in this connection, whereas the writer, although recognizing the importance of these factors, wishes to emphasize the *age* of the child at the onset of the disease. Five years of sickness between the ages of five and ten, it is believed, will produce a more serious retardation than five years of sickness between the ages of fifteen and twenty. It will do so because the period of natural growth and development is affected in the first case and not particularly so in the second case.

Group B (hookworm children who were not treated) improved least mentally, making an advancement of only 34%, namely about one-third as much as that made by A.

Group C (children who were completely cured of their hookworm infection) improved almost double as much as did the non-treated (34%) hookworm children and three-fifths (60%) as much as did the non-infected group.

Group D (a hookworm group with severer infection than that shown by C, and one which was treated but not completely cured) made 38%, only a slightly greater improvement than the apparently more lightly infected but untreated group (B, 34%) and considerably less improvement than that (60%) made by the less severely infected but completely cured group (C).

An older subgroup of D (Du) of treated but incompletely cured severer cases improved only 9% as much as the normal children (100%), and very much less than the untreated younger children (B, 34%).

Conclusion.—The figures show, then, that hookworm disease unmistakably affects mental development. *Treatment alleviates this condition to some extent but it does not, immediately at least, permit the child to gain as he would if he had not had the disease. And the figures apparently further show that prolonged infection may* *produce prolonged effects upon mentality—effects from which the individual may never entirely recover.*

This investigation by psychologists bears out the claims advanced but not measured by physicians and zoologists that the effect of hookworm infection may result in serious delay in development of mental activities of children and of communities, and may therefore have a seriously inhibitive effect upon the school problems and even upon the economic development of hookworm communities.

It emphasizes more than does any previous study the advisability of prompt medical treatment even of light cases, for the benefit of the children themselves and collectively for the better development of the community.

INTRODUCTION

The *purpose of the investigation* reported here was twofold:

(1) To discover what effect hookworm disease had on physical and mental ability of school children, and

(2) To discover what effect treating hookworm disease had upon the physical and mental life of such children.

Relation of this report to that of Dr. Stiles. In order that the results of the mental tests may be thoroughly understood a very brief statement is given below of the salient features of the procedure of carrying on the investigation. In the work of C. W. Stiles* will be found a statement of the conditions under which the research work was carried on. He had charge of the physical, clinical and zoological aspects of the whole investigation, while the writer had charge of the mental phases of the subject. A number of the physical tests (such as height, weight, grip and spirometer) which were carried on by Dr. Stiles are included here. These physical tests, however, formed but a very small part of the physical examination, which was most thorough and exhaustive, covering every part of the body, including such details as condition of the skin, hair, teeth, etc. Blood tests were used covering a count of red and white corpuscles and the percentage of hemoglobin. In addition, as exact a history as possible was obtained of the child's sicknesses, together with a statement of the sanitary condition of his home.*

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* C. W. Stiles, "Public Health Reports," Washington, D. C., 1916.

The following details as to the procedure of the investigation are considered simply in the light of the mental tests which follow:

1. The three examinations.
2. The time of the treatment.
3. The children who were tested.
4. The division of the children into groups.
5. A preliminary survey of the mental and physical condition of the different groups of children.
6. The methods employed in working up the data.

1. **Three examinations** were made of the children included in this study. The first occurred during August and September, 1912, the second in the last week of October and first week of November, 1912, and the third during the last two weeks of February, 1913. The first examination was devoted to a preliminary survey of the field, the selection of children for the study,

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* The writer wishes to take this opportunity of acknowledging the faithful and efficient work which Mr. Thomas R. Garth, then a graduate student at Columbia University, rendered as assistant in the field work.

and the physical examination of a large number of these children. The second examination was restricted to 126 children. Their physical condition was re-examined to some extent and their mental condition was tested for the first time. Three and a half months later (0.3 years) the third examination was made. This was an *exact* repetition of the earlier examinations and included 115 children.

It must be remembered, then, that the first psychological tests were given at the time of Examination II, and that the second psychological tests were given at the time of Examination III.

2. **Treatment.**—Immediately after the second examination Dr. Stiles commenced treating the children who had shown microscopic proof of hookworm infection. Four rounds to the different schools were made, so that there was a possibility of four treatments to any child. The plan was to give a small dose of the thymol and later repeat the treatment if the child still gave microscopic evidence of infection. But, due to failure of the children to come in for the treatments, there was great irregularity in the number given the various children. As a result of the treatment 36 children were completely cured and many others were partially cured.

3. **The children who were tested.**—A careful description of these children is given in the

report of Dr. Stiles. A short restatement concerning those details which are of special interest to the psychological tests is made here in order that the situation may be clearly in mind.

In the six schools all the children between the ages of 10 and 12 were tested: and also some children between 9 and 10 and some between 12 and 13, according as we had the time to give to them. Besides these children a number of older children were studied who had unmistakably bad cases of hookworm infection. At the time of the second examination (the first psychological examination) 126 children were tested. We were able to re-test 115* of these children in the third examination. Of the 12 that we were unable to re-test, Case No. 493 had died, Case No. 408 was sick in bed, Case No. 339 had moved away, Case No. 429 was away on a visit, and Case No. 487 was re-tested but made a very poor showing, due to misbehavior of her older sister (No. 486), who wanted to go home. She was one of the brightest girls for her age, but it seemed best to exclude her, as she did not have a fair show to do her best work. The remaining seven subjects refused to co-operate, the first five by not taking the second psychological tests, and the other two by refusing to bring specimens so that they could be classified. The seven (together with their actual and Binet age according to the first test) were No. 340 (10.5 and 7.6), No. 397 (14.2 and 9.0), No. 447 (14.5 and 8.7), No. 463 (15.9 and 7.6), No. 486 (12.4 and 8.2), No. 434 (10.8 and 7.8), and No. 495 (10.0 and 7.8). These seven were "selected" mainly, according to the writer's judgment, on the basis of inability to do the tests satisfactorily and a desire to avoid the humiliation of failing again. The loss of the first five of the 12 can be ascribed to accident and so has no effect on the total results.

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* But only 114 were retested for their mental condition.

The loss of the last seven, who, as we have seen, had been among the poorest in the second examination, would naturally tend to raise the average of the remainder at the third examination. However, four of these seven were older than 12 and so do not come into our standard groups. Consequently the error, though unfortunate, is not particularly large.

4. **Division of Children into Groups.**—On the basis of the microscopical tests, the children were sub-divided into the following groups:

Group A. Negative Controls.—Group A is composed of 22 children.*

These 22 cases all showed no infection at the first examination, and only Subjects No. 356 and No. 392 showed infection at the third examination. But this infection was so slight and recent* as to furnish no particular warrant for excluding them from this group.

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* Stiles has 23 children in this group. But Subject 408 of this group of 23 was sick at the time of the third examination and so could not be tested by us.

Group B. Positive controls.—This group contained 12 children who showed hookworm infection at the first examination and who were not treated at all.

Group C. Completely cured.—This group contains 36 children who at the first examination showed microscopically positive evidence of infection, and who after one or more treatments gave negative microscopic results.

Group D. Incompletely cured.—This group of 32 children still showed infection after one to four treatments.

Group E. Treated, result unkown.—These 14 children were treated from one to four times, but they refused specimens later and the final result of the treatment is therefore unknown. Stiles has but 12 children in this group. The difference between our two groups lies in the fact he assigns Case No. 495 to his Group F—Miscellaneous Cases—and Case No. 434 to his Group G—Residual Cases. As there is no difference from the point of view of the psychological part of this investigation between Stiles' Groups E, F and G, these two cases are placed in our Group E.

But inasmuch as only between the ages of 10 and 12 were *all* the children tested, and considering also that outside these limits in age only a few scattering cases were obtained in Groups A and B, it has seemed best to confine our study to the children in the above groups who were from the ages of 9.9 to 12.0 years of age, inclusive. As Group D has 12 individuals over the age of 12, we have enough cases to base an average upon. Of the 12, 11 are between 12.1 and 14.9 years of age, and 1 is 18.8 years old. It has seemed best to consider only the 11 and omit the 18.8-year-old subject, thus making the group more homogeneous.

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* It might possibly have been overlooked at the first examination because the infection was so slight.

These older children are considered in comparison with the younger children in the same group. An attempt to use the older children in Group C likewise was made, but, owing to the fewness of the cases and the fact that they were widely separated as to performance, it had to be given up, for no valid conclusions could be deduced. Our groups as used in this study consist of:

Group									
As,*	8	children	9.9–10.9	years	old	and	10	children	11–12.0
Bs,	9	"	"	"	"	"	0	"	"
Cs,	15	"	"	"	"	"	12	"	"
Ds,	6	"	"	"	"	"	11	"	"
Du,	11	"	12.1–14.9	"	"				

---

* To distinguish the groups of children used here from those used by Stiles, they are designated as As, Bs, Cs, and Ds, instead of A, B, C, and D. Our groups are restricted to those children between the ages of 9.9 and 12.0 years, inclusive. "Du" refers, of course, to that sub-group of Stiles' Group D, which is composed of children between the ages of 12.1 and 14.9 years.

The members of Group E are not considered at all, because we do not know their final condition as respects infection. As there are but seven individuals in the group between the ages of 10.0 and 12.0 years, the discarding of these data cannot be considered important.

Conclusion.—(1) The main psychological investigation is concerned with the children between the ages of 10 and 12 in the following groups:

Group As—	18	normal children.
Group Bs—	9	untreated hookworm children.
Group Cs—	27	completely cured hookworm children.
Group Ds—	17	incompletely cured hookworm children.
Total,	71	children.

(2) A second phase of the investigation as to the effect of age upon development after treatment considers 11 older children in Group Du in addition to those given above, making a grand total of 82 children considered in the psychological part of this study.

5. **Preliminary survey of the mental and physical conditions of the different groups of children.**—The data furnished by Dr. Stiles show quite clearly that at the time of the first and second examinations (*i. e.*, before treatment) Group As was in the best physical condition, Groups Bs and Cs were about equal, and Group Ds was in the poorest condition. The same condition is

pictured by the Binet-Simon tests. The data are as follows:

	As	Cs	Ds	Bs
Difference between Actual Age and Apparent Age..	−1.1 yr.	−1.5 yr.	−2.2	−1.4 yr.
Difference between Actual and Binet Age..........	−1.0 yr.	−1.6 yr.	−2.2	−1.2
General Good Health......	61%	56%	24%	56%
Hemoglobin..............	85	77	65	74
Red Corpuscles, percent. of 5,000,000...............	92	86	83	81

It must be borne in mind, then, in comparing the improvement made by Groups Cs and Ds (the treated children) with Group Bs (the untreated) that the latter group had approximately the same degree of infection (so far as can be judged from other data) as Group Cs, and was not in so bad a condition as Group Ds. Our control squads represent a normal group of children (Group As) and a rather lightly infected Group (Group Bs), not a severely infected group of children. Undoubtedly the differences which we find between the improvement of the treated and the non-treated hookworm groups would have been far greater if Group Bs had represented a more serious degree of infection.

The presence or absence of enlarged tonsils and adenoids, of course, could have a great effect upon the changes in mental condition. Groups As and Cs are favored here, in that several operations for their removal took place between Examinations II and III. Dr. Stiles reports a slight improvement for these two groups in this matter and a slight decrease for Groups Bs and Ds.

6. **Methods of handling data.**—Off-hand, it would seem that the most natural method of handling the results would be to obtain the averages of each group before and after treatment and then to compare these *averages* in order to determine the various factors under study (Method I). But such a method in the present case is not applicable at all. Two reasons are sufficient to show this. First, in those cases where we have a number of failures (as in the calculation test), there is no way of including such subjects in the group average. And secondly, in the case illustrated in Table I, it is apparent that the average is most misleading. There are shown the results from Groups As and Ds in the form-board test. The averages for Group As in the two tests before and after the treatment are 16.9 and 15.1, showing an improvement of 1.8 seconds on the part of the control squad, while the improvement on the part of the incompletely cured group is 2.4 seconds. Apparently the latter group has improved faster than the normal children. But if we eliminate the record of Subject No. 398, who made a much greater improvement than any other individual,

we find that the improvement of Group Ds averages exactly the same as the control squad, *i. e.*, 1.8 seconds. The point here is that, if Case No. 398 had not been considered, if he had been absent from school during the examinations, then the averages would have shown an equal improvement for both groups; but, seeing that he was present, the data indicate that Group Ds has advanced the most. This is not the only case of this sort; in fact, it occurs in almost every test, and the odd case is never to be found in the control squad. Why? Because these children, free from hookworm disease, make such good records the first time that they cannot beat them very much the second time. The error from including such cases as No. 398 is then always in favor of making out that the treatment produced better results than it actually did. But, on the other hand, arbitrarily to exclude cases is but a step toward making results read as one will.

Now, if instead of the average the *median* (Method II) is used to indicate the central tendency of the two groups, we do away with the difficulty connected with the presence of failures in a group. And, moreover, the median is not affected by the improvement of an extreme case, such as has been referred to under the discussion concerning averages. But there is an objection to the use of medians, which militates greatly against their use. This

TABLE I

Illustrating Three Different Methods of Determining the Relative Gains in the Form-Board Test of Groups As and Ds during 3½ months. Method I—Relative Gains Determined by Comparing the Gains of the Two Groups as Based on the *Average* Performance in Exam. II and Exam. III. Method II—Relative Gains Likewise Determined, but Using *Medians* Instead of Averages. Method V—Relative Gains Determined by Comparing the Gains of the Two Groups but Limiting the Comparison to "Equal-Sub-Groups" from the two Groups.

Division into Sub-Groups	GROUP AS CONTROL SQUAD						GROUP DS INCOMPLETELY CURED GROUP					
	Considering Entire Group W			Considering Sub-Groups X			Considering Entire Group Y			Considering Sub-Groups Z		
	Subjects	Exam. II	Exam. III	Exam. II	Exam. III	Gain	Subjects	Exam. II	Exam. III	Exam. II	Exam. III	Gain
	381	13.4	13.2									
	496	13.8	13.2									
	368	14.0	12.2									
	393	14.0	12.8									
	374	14.6	16.0									
N* 13.1–15.0........	378	14.6	13.6	14.07	13.50	0.57						
	349	15.2	18.2				355	15.4	14.4			
	364	15.6	11.6				330	17.0	16.0			
	377	16.0	14.4				344	17.0	14.0			
	392	16.2	12.8									
O 15.1–17.0........	380	16.4	14.0	15.88	14.20	*1.68*				16.47	14.80	*1.67*

P	17.1–19.0........	375	17.6	16.6	17.60	16.60	*1.00*	454 388	17.6 18.8	21.4 17.2	18.20	19.30	− *1.10*
Q	19.1–21.0........	497 352 389 376 363	19.2 20.0 20.0 20.6 20.8	15.2 14.2 17.2 17.2 21.6	20.12	17.08	*3.04*	452 483 474 453 342	19.2 20.0 20.0 20.0 20.4	14.2 17.4 22.4 16.2 19.2	19.92	17.88	*2.04*
R	21.1–23.0........	411	22.2	17.4	22.20	17.40	*4.80*	437	21.2	17.6	21.20	17.60	*3.60*
S	23.1–25.0........							475 450	23.6 24.0	19.4 21.8	23.80	20.60	*3.20*
T	25.1–27.0........							472	26.0	20.0	26.00	20.00	*6.00*
U	27.1–29.0........							442	27.4	29.0	27.40	29.00	− *1.60*
V	29.1–31.0........												
W	31.1–33.0........							398	31.8	21.0	31.80	21.00	*10.80*
Method I	Average....		16.9	15.1					21.2	18.8			
	P. E.......		*.5*	*.4*					*.7*	*.7*			
	Gain.......			*1.8*						*2.4*			
Method II	Median.....		16.1	14.3					20.0	18.4			
	P. E.......		*.6*	*.5*					*.7*	*.6*			
	Gain.......			*1.8*						*1.6*			
Method V	Average of sub-groups O, P, Q, R..				18.95	16.32					18.95	17.40	
	Gain..........................						*2.63*						*1.55*
	% Gain in terms of Exam. II.......						*13.9*						*8.2*

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* Sub-groups arranged on the basis of initial performance; *i.e.*, performance in Exam. II. Sub-group N includes those children with an initial ability between 13.1 and 15.0 secs.; sub-group O between 15.1 and 17.0, etc.; up to sub-group W, which includes those with an initial ability between 31.1 and 33.0 secs.

objection applies equally well to the average as to the median. It lies in the fact that the children in the different squads are different selections, selections so different that in some cases the normal squad and the squad of incompletely cured children overlap but slightly (*i. e.*, in the case of the second test in logical memory 0% of the incompletely cured group reach the median of the normal group and but 25% reach the —P. E.*). Such being the case, the respective improvements in time, determined by the average or the median, cannot be used as a measure of the relative gains of the two groups. A concrete case will make this point clearer. Suppose we have two athletes, A and B, who on January 1st could run the 100 yard dash in 16 seconds and 10.5 seconds, respectively. And after a year they can run it in 14 seconds and 9.5 seconds, respectively. A then has improved 2 seconds to B's 1 second; he has cut down his time moreover by 12½%, while B has cut down his time by 9½%. According to the figures then A has improved more than B, whether the actual or relative amount of improvement in time is considered. But surely no one for a moment would consider that A's improvement during the year was anywhere near as great as B's improvement. A's performance at the end of the year is still poor, while B has advanced from good time to the best time known to athletics. For him to equal either A's actual improvement of 2 seconds or his relative improvement of 12½% would require him to run faster than any man has ever run. The discrepancy here between the seemingly greater improvement of A according to the figures, and the actually greater improvement of B according to the world's estimate, is due to the fact that *equal improvements in time do not necessarily correspond to equal improvements in performance.* It is then impossible to compare the improvements in time shown by A and B and deduce any conclusion as to their respective gains. This is exactly the situation confronting us in comparing the performances of the various groups, except that the various groups do overlap more or less and to that extent they can be compared. Turning back to Table I we now see that the improvement of 1.8 seconds over the average of 16.9 seconds of the control squad is not comparable to the improvement of 2.4 seconds over the average of the 21.2 seconds of the incompletely cured squad. Although the improvement in seconds of the former is less than that of the latter, yet it possibly may represent a really greater improvement in actual performance. We cannot tell what the real situation is from such figures.

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* If one imagines all the children in Group As arranged in the order of their ability to remember the story and then divides this group of 18 children into four equal groups, the dividing points of the four groups, starting at the poorest end of the group, are called, respectively, —P. E., median, and + P. E. Below the grade, then, of the —P. E. are one-fourth of the children, between the grade of the —P. E. and the median are one-fourth, etc. The statement in the parenthesis in the text means, therefore, that none (0%) of the children in Group Ds was as proficient in this memory test as the poorest child among the best one-half of Group As. It also means that only 25% of Group Ds were more proficient than the poorest child among the best three-fourths of the whole As group. With the use of such figures we can present a comparison of the distributions of the two groups. To repeat: none of the children in Group Ds is equal to the best one-half of Group As, and the best 25% of Group Ds are equal to the fourth quarter of Group As.

(In this entire report the P. E. is really the Quartile, as defined by E. L. Thorndike, "Mental and Social Measurements," 1913, page 40: "half the distance between the 25 percentile measure" (—P. E.) "and the 75 percentile measure" (+P. E.).

Another example of this situation might be given. Ayres* developed a scale of handwriting in which the steps on the scale are made equal, that is, handwriting with a grade of 40 is as much superior to that with a grade of 30 as it is inferior to a handwriting with grade of 50. He gives the number of words that can be read per minute for typical specimens of the various grades from 20 to 90 on his scale. His data are as follows:

Grade....	20	30	40	50	60	70	80	90
Rate per Minute.	131.2	149.4	163.5	175.7	186.1	195.8	202.9	209.6
Difference.		18.3	14.1	12.2	10.4	9.7	7.1	6.7

Hence it follows that X with a grade of 20, Y with a grade of 40, and Z with a grade of 80, in order to improve an equal amount on the scale, must show gains in the rate their handwriting can be read of 18.3 words, 12.2 words, and 6.7 words per minute, respectively. Without a knowledge of this scale one might suppose that X (in round figures) had gained 3 times as much and Y 2 times as much as Z. (Even if stated in terms of percent the gains are 14%, 7% and 3%, respectively.) But actually the gains are equal. This illustrates our difficulty in comparing groups of children with different initial abilities. A comparison based on their improvement measured in time is simply comparable to the comparison of 18 words, 12 words and 7 words above, which we have said is most misleading.

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* L. P. Ayres, "A Scale for Measuring the Quality of Handwriting of School Children," *Russell Sage Foundation Bull. No. 113*, Dept. of Child Hygiene.

A third method of handling the data is that of determining the median ability (and also the —P. E. ability) of the normal squad for both tests and then stating in terms of percent of the total number in the second group how many of them surpass this median (as well as the—P. E.) standard of the normal children in both tests* (Method III.)

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* See Norsworthy's study of mentally deficient children (N. Norsworthy, "The Psychology of Mentally Deficient Children," *Archives of Psychol.*, 1906, No. 1) for an example of the use of this method, or, more recently, the work of Simpson (B. R. Simpson, "Correlations of Mental Abilities," *Teachers' College Contributions to Education*, 1912, No. 53), in which the abilities of 17 individuals of a high grade of intellectual ability are compared with the abilities of 20 individuals of a low grade of efficiency. (See, also, E. L. Thorndike, "Educational Psychology," Vol. III, Part II, 1914.)

Such results in the case of Table I would be as follows:

Group As median, Test I. 16.0 secs. 8% of Group Ds reach or surpassed it.
Group As median, Test II. 14.4 secs. 19% of Group Ds reach or surpassed it.
Group As—P. E. Test I. 20.0 secs. 54% of Group Ds reach or surpassed it.
Group As—P. E. Test II. 17.2 secs. 42% of Group Ds reach or surpassed it.

From such data it appears that 11% more of Group Ds have reached the median performance of Group As in the second test than in the first test, while, if the —P. E. is used as the standard instead of the median, 8% less of Group Ds have reached the proficiency of the best 75% of Group As in the second test than in the first test. From such results it is difficult to determine just what the true situation is. The discrepancy between the 11% gain, measured in terms of the median, and the 8% loss, measured in terms of the — P. E., is due, in part at least, to the large probable error accompanying the determination of a median or — P. E. with so few cases. In other words, the probable error accompanying such determinations covers up the differences which we are endeavoring to discover. But that as much light as possible may be thrown upon our work, the results obtained from the use of this method are set forth in a subsequent section (see pages 87 to 92.)

Still a fourth method will occur to many. Here the *gain in percent* of each child is determined for each experiment (Method IV). An average (or median) of these percents for all children in a group is taken to represent the gain of the group. Comparisons can then be made between the different groups just as desired. At first thought this method would seem to be valid, but careful study shows, just as in the case of the two hundred-yard runners, that the poor performer can more readily show a high percent gain than can the performer who is good at the start. Of the four methods so far presented this one would be fairest, and in many situations, where the difference between the best and poorest performers is not very great, it would be accurate enough. But, unfortunately, in our case this difference between the two extremes of performance is very great. We must then discard this method for still another.

The final method employed to determine the relative gains of the different squads during the interval between the two tests was suggested by Winch's *"equal-group" method** (Method V).

In studying the influence of various factors upon school children, such as the effect of a drill in mental arithmetic upon proficiency in other arithmetical tests, Winch would divide a group of children into two groups so that the ability of the two groups in arithmetical work should be equal at the start. This equality was secured, moreover, by setting over against each other, the two best, the next two best, the third two best, etc., down to the two poorest. In this way the small improvements in time that were shown by the best children would be equally distributed in the two groups, and likewise the large gains in time shown by the poorest children would be equally distributed in the two groups. In other words, the selection was equal in both groups. Now this method cannot be applied in our case in exactly the manner that Winch has done, because we were not free to divide our children up into groups as we saw fit, but have been forced to take the groups as we found them. But we can, however, deliberately set to work and with what material we have now construct equal groups as to proficiency in the several tests. And this is what we have done.

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* For example, see W. H. Winch, "Mental Fatigue in Day School Children as Measured by Immediate Memory," *Journ. Educ. Psychol.*, 1912, III., 18–28 and 75–82.

The data in Table I will illustrate our method probably better than we can describe it. These data are taken from Table VII, which gives the results of the Form-board Test. In that test, considering all the children together, the best performance was made in 13.4 secs. and the poorest in 31.8 secs. The children in the several groups were sub-divided into eleven sub-groups, according to their performance in Examination II, the first sub-group (N) being composed of those who did the test between 13.1 and 15.0 secs., etc., down to the last sub-group (W), which was composed of those who did the test between 31.1 and 33.0 secs. Such a subdivision is shown in Table I. Column W gives the individual records for Group As, and Column X gives the averages of the sub-groups (N, O, P, Q and R) as they have been made up from the individual records. For example, the six best individuals in Group As did the test between 13.1 and 15.0 secs., and so they are placed in sub-group N, the average of their six records appearing in Column X. In the same way the sub-groups of Group Ds are determined (see Column Z). On making a comparison of the sub-groups in Columns X and Z, it is apparent that Column Z lacks sub-groups N and V, and Column X lacks the sub-groups S, T, U, V and W. Consequently, in making our comparison of Groups As and Ds, we eliminate sub-groups N, S, T, U, V and W and confine our attention to the sub-groups O, P, Q and R, which are present in both Groups As and Ds. An average is then obtained of these four sub-groups, as shown in the Table. Here we find that Group As improved from 18.95 secs. to 16.32 secs. (a gain of 2.63 secs.) and that Group Ds improved from 18.95 secs. to 17.40 (a gain of but 1.55 secs.). As the initial performance was exactly equal in the two Groups, the amount of improvement shown in seconds is then an accurate measure of the gain in proficiency of the two Groups. It is evident that the Control Group has improved considerably more than the children who were treated but not completely cured. These gains, if expressed in terms of percent of the initial performance, are for Groups As and Ds 13.9% and 8.2%, respectively.

Now let us stop and consider the wisdom of these steps. Why sub-divide the Groups into sub-groups? And why eliminate from final consideration sub-groups that are not common to both groups? The same reason answers both of our queries. Turning to Column X, we see that normal children who can do the form-board test in 13.1 to 15.0 secs. can gain 0.6 secs., children who can do the test in 15.1 to 17.0 secs. can gain 1.7 secs., children who can do the test in 17.1 to 19.0 secs. can gain 1.0 secs., children who can do the test in 19.1 to 21.0 secs. can gain 3.0 secs., and children who can do the test in 21.1 to 23.0 secs. can gain 4.8 secs. This being the case, to state that a child has gained 3.0 secs. means nothing definite at all, unless at the same time the initial performance of that child is also given. For if the child did the test the first time in 14.0 secs., then the gain of 3.0 secs. is phenomenal; if the initial performance was 20.0 secs., the gain is what is to be expected; while if the initial performance was 22.0 secs., the gain has been only about one-half of what should be made. Consequently, *gain in performance when stated in* *terms of seconds must always be accompanied by a statement of the initial performance.* And hence, if the initial performance of two groups is different, no comparison of their gain in seconds can be made. This is the chief reason that the gains of 1.8 secs. for Group As and of 2.4 secs. of Group Ds, as obtained from averages of the whole groups, cannot be accepted, for the average initial performance of Group As is 16.9 secs. and that of Group Ds 21.2 secs. It should now be clear why the sub-groups are established and why only those sub-groups are considered which are common to both Groups under study. By this means we obtain gains in the two Groups which are made in terms of equal initial performances.

Another way of stating the same reason for our use of this method of "equal sub-groups" is this: Group As is composed of children whose gains in performance can be expected to be only a small one when expressed in terms of time, while Group Ds is composed of children whose gains in performance can be expected to be relatively larger. Hence, if the average gains of As and Ds are compared, Ds must show the larger gain. In other words, other things being equal, that group which has the poorest initial performers will always show the largest gain when the gain is measured in terms of time or amount. But when only sub-groups from both groups which are equal in initial performance are compared, then the gains which are found are indicative of the real situation.*

In considering these sub-groups one should view them no longer as representing the performance of individuals, but rather that of different groups of individuals—groups which differ by certain amounts when first tested. Viewed in this way, we see that normal individuals, who do the form-board test in 13–15 secs., as already stated, can gain 0.6 secs. in 3½ months; those who do the test in 15–17 secs. can gain 1.7 secs.; those who do the test in 17–19 secs. can gain 1.0 sec.; those who do it in 19–21 secs. gain 3.0 secs., and those who do it in 21–23 secs. gain 4.8 secs. Hence it cannot be argued against this method that we arbitrarily weight the results of some individuals more than others in obtaining our final results—*i. e.*, one individual makes up the sub-group P and five make up the sub-group O, but each sub-group equally affects the final average. Actually we do do this, but it is because of the paucity of our material that it is done. And, moreover, when we weigh sub-group P (based on one individual) with sub-group O (based on five individuals), we do not any longer think of the sub-groups as the records of so many individuals, but rather as representing the best measure we can obtain of what all normal children with these initial abilities would do under similar circumstances. The objection should lie, then, not against weighting one individual more than another, but rather that the gains indicated for sub-groups made up of different initial abilities are not very reliable and that some are much less reliable than others (*i. e.*, the reliability of sub-group P being to that of sub-group O as the $\sqrt{1} : \sqrt{5}$).

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* Warner Brown's recent monograph ("Habit Interference in Sorting Cards," *Univ. of Calif. Pub. in Psychol.*, 1914, I, No. 4) illustrates the need for just such a method as this. His method of handling the data is very similar to ours.

There are some other objections to this method of determining the relative improvement of the different groups. First of all, it is necessary to eliminate a number of cases from each group in practically every comparison. This cuts down the number of cases which are used in the final determinations, when already the total number of cases in the groups is none too many. Hence the probable error of our final conclusion is perceptibly raised. Secondly, the comparison is necessarily made between the poorer members of the control squad and the better members of the hookworm squad. This cannot be avoided. It possibly favors the hookworm groups, making their indicated gain greater than it should be. Third, the comparison between any two groups in one experiment will be made in terms of certain subjects in the two groups, and in another experiment the comparison will be made between another set of subjects in the two groups. Consequently, comparisons between different experiments can only be made in a very broad and general way, because the same subjects have not been used in both cases. This difficulty does not affect the direct results we are seeking in this investigation, but it does affect an otherwise valuable by-product—the comparison of improvement in the several tests.

Still a fourth objection occurs in some of the tests; for example, in the Memory Span test. Some of the children who obtained a memory-span of 8 at the time of the first test probably did so by chance; that is, occasionally they can obtain such a record, but not consistently so. When the second test is made, some do not then achieve this high record. The sub-groups who had a memory span of 8 at the time of the first test will show a loss—a loss not in keeping with the gain shown in the other sub-groups. But this loss is really due to chance, and equals another chance gain which enters into the total gains shown in sub-groups with spans of 7 and 6, for among those individuals some now have by chance a span of 8. The objection to our method, then, is that in the best sub-group there is a chance good performance in the first test that will not appear in the second test, and that causes the best sub-group always to show a smaller gain than is really proper. The same holds true of the poorest sub-group, but here the error is to make it appear that this sub-group has gained more than it should. It is for this reason that the relative gains in the Memory Span Test (see Table on page 59) are based not on the sub-groups with the spans of 8, 7, 6, and 5, but on spans of 7, 6, and 5 alone. This was done all the more because in no case were there more than two individuals in the sub-groups with a span of 8.

Notwithstanding the objections which have been pointed out, it seems best to use this method in the final determinations of just how the hookworm children improved as compared with the normal children. In fact, it and Method III seem to be the only methods of handling the data which give an unequivocable answer when the several data are compared. But the determinations from Method III are more difficult to explain, and so our chief results are based on Method V. As far as it is possible to evaluate results of such different meanings as are obtained in Methods III and V, it seems that they both point to the same conclusions.

THE MENTAL TESTS

In this section are presented the results obtained from the mental tests upon several groups of hookworm and non-hookworm children.

The tests, as used, were as follows:

1. Opposites Test.
2. Calculation Test.
3. Logical Memory.
4. Memory Span.
5. Handwriting.
6. Form-board Test.
7. Binet-Simon Test.

These tests will be considered in the above order, the method being presented first and the results afterwards.*

After these seven tests have been considered there is presented a comparison between children between the ages of 10–12 in Group Ds, and children in the Group Du between the ages of 12 and 16. At the close of this section a summary is given showing the results as obtained from the seven tests as a whole.

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* There was no uniform procedure as to whether Mr. Garth or the writer should test the child first, nor did either of us always test the children in the same order, due to local conditions which very often absolutely prevented the carrying out of a uniform procedure. But in the main, the writer had the child first of all tap 400 times (the tapping test and the fatigue test are included among the physical tests, see page 102), then obtained his memory span, then determined his mental age with the Binet-Simon tests, and finally had him tap 400 times again. Mr. Garth used the form-board test first of all, then the calculation and opposites tests, and then followed the reading of the story aloud and finally writing it from memory. The tests occupied about 25 minutes for each of us. The writer should like to have used still other tests, but circumstances demanded that not more than half an hour should be devoted by either of us to any child.

1. **Opposites test.**—The test consists in measuring the lapse of time between hearing a common word and pronouncing its opposite in meaning, as "long—short," "soft—hard," etc. In order to arrange a test which would be applicable to bright children in the fifth grade and dull ones in the first grade, it seemed best to use a list of 20 words which had associated with them very common and familiar opposites.*

It seemed best to measure the time taken in responding to each stimulus word instead of taking the time for responding to the whole 20 words, as is generally done. The failure to think of one "opposite" could not then prolong the time of an otherwise very good record much beyond that of a record from rather slow responses. The procedure, consequently, consisted of explaining very carefully what was wanted, and then practicing the child with a number of trial words. After it was certain the child understood, the list of 20 words was read one after the other, and the time taken in responding was measured with a stop-watch. Responses that were not exactly correct but which had some merit, such as "dirty—white," "lost—here," were credited as half correct. In such cases the reaction time was increased by half again as much. The reaction time of responses that were incorrect was doubled. This method of accounting for errors by increasing the response time is purely arbitrary, but has the great advantage of being easily performed and, as the median (not the average) time of the 20 reaction words was used to express the central tendency, it resulted that these penalties simply increased the number of slow responses and so raised the median. In only 6 out of 292 cases was the median based upon any such "computed" time. In five of these six cases the median thus obtained was a fair measure of the central tendency, but in the sixth (No. 411 in the second test) it was not. Here a large number of mistakes had been made, and if they had been scored as failures the median-time would have been 7.2 secs. instead of 5.2. And, on the other hand, if the subject had had one more fast response (having nine equal to 2.2 or better), her median-time would have been 3.7. It has seemed best, consequently, to throw out this single case on the ground that the median in her case is so extremely unreliable that it probably does not represent her true ability at all. This is the more clearly made certain when it is realized that her first record gave a median of 2.1 secs. No other child improved as much as a second in the two tests, but here her deficiency is 3.1 seconds.

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* The twenty words which were used here were: long, soft, white, far, up, smooth, early, dead, hot, asleep, lost, wet, high, dirty, east, day, yes, wrong, empty, and top.

An improvement on the method used here would be to use the present list of easy words (but substituting two others for "far" and "wrong"—words that are difficult for many children to understand) and add a list of 20 harder words, counting the two lists as separate tests. The first list is too easy for the brighter children and becomes more a test of speed of pronunciation than of association. The second test would be too difficult for the duller children, but would test the brighter ones.

Table II gives the median reaction-times in this test for the various groups. Groups Cs and Bs are equal in Examination II; Group Ds is next, and As last. That Group As should be so slow is rather surprising. When the results from Examination III are considered, however, Group As appears very much superior to Groups Cs, Ds, and Bs. Cs and Ds are equal, and Bs is poorest. According to the medians, Group As has improved 0.57 sec.; Ds, 0.43 sec.; Cs, 0.20 sec., and Bs, 0.17 sec.

When the amount of the improvement is studied by our "equal-group" * method we find that Group As gained 0.41 sec. (24.2%); Group Ds, 0.22 sec. (13.1%); Group Cs, 0.05 sec. (3.0%), and Group Bs, 0.05 sec. (2.9%).

Conclusion.—(1) In Examination II the Control Squad As was poorest, with a median response time of 1.97 sec.; the Completely Cured were first (1.75 sec.); the Non-treated were second (1.77 sec.), and the Incompletely Cured were next to last (1.90 sec.). In Examination III the Control Squad had a response-time of 1.40 sec., the Treated children an average response-time of 1.51 sec., and the Non-treated of 1.60 sec.

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* On pages 31 to 39 is given a detailed discussion as to the reason for using this method of computing the data, and also an explanation of the details in such a table as Table II.

(2) As to improvement: the Control Squad (As) improved 24.2%, the Treated children 8.1%, and the Non-treated 2.9%. The gain in the Incompletely Cured (13.1%) is greater than that of the Completely Cured (3.0%).

In many different investigations it has been found that the opposites-test correlates very high with "general-intelligence," using this term in the ordinary popular sense of the word. In fact, the test very often correlates higher than any of the other tests used. In two investigations somewhat similar to this one, that come to mind, the opposites-test separates more distinctly than any other test the good performers from the bad. In Norsworthy's* study of mental defectives 0% of the defective children surpassed the median ability of the normal children and only 1% surpassed the ability of the poorest 25% of the normal children. In Simpson's† study of good

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* N. Norsworthy, "The Psychology of Mentally Deficient Children," *Archives of Psychol.*, 1906, p. 68.

† B. R. Simpson, "Correlations of Mental Abilities," *Teachers College Contributions to Education*, 1912, p. 52.

TABLE II

Opposites Test.* Giving the Median Association Time in Seconds for Twenty Responses

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group																
Median.......	†17	1.97	1.40	0.57	27	1.75	1.55	0.20	17	1.90	1.47	0.43	9	1.77	1.60	0.17
P. E. of Med..		*0.09*	*0.03*			*0.07*	*0.03*			*0.04*	*0.04*			*0.07*	*0.05*	
Sub. Groups																
M 1.00–1.29					2	1.13	1.40		1	1.06	1.47					
N 1.30–1.59	5	1.47	1.21		7	1.40	1.37		2	1.39	1.29		3	1.43	1.55	
O 1.60–1.89	2	1.61	1.21		9	1.71	1.52		5	1.70	1.61		3	1.76	1.58	
P 1.90–2.19	3	2.00	1.43		2	1.95	2.03		6	1.96	1.48		2	1.93	1.84	
Q 2.20–2.49	3	2.32	1.45		4	2.29	2.03						1	2.20	1.55	
R 2.50–2.79	1	2.70	1.45		3	2.60	1.72		1	2.50	1.77					
3.10–3.39	1	3.10	1.43													
3.40–3.69	1	3.50	2.03													
4.30–4.59									1	4.40	3.40					
5.50–5.79	1	5.60	1.90													
Failure									1	F	2.70					
Av. N, O, P..	10	1.69	1.28	0.41	18	1.69	1.64	0.05	13	1.68	1.46	0.22	8	1.71	1.66	0.05
% Gain......				*24.2*				*3.0*				*13.1*				*2.9*
Ratio of Gain.				100				12.2				53.7				12.2

* See pages 31 to 39 for explanation of this Table.

† Case No. 411 omitted. See text for reason.

intellects and poor ones, represented by college professors and graduate students on the one hand, and inmates of a Salvation Army Industrial Home, etc., on the other hand, we have an even greater difference between the two extremes. For here 0% of the poor intellects surpassed or reached the ability shown by the poorest member of the good intellects. Consequently, we should expect in our study a noticeable difference in the ability of the children in the various groups and also a difference in ability to improve, since we know that there is a big difference in the grades to which they have attained in school. Group As should be markedly superior to the others, with Cs, Ds and Bs about equal, or possibly Ds the poorest of all. Our data confirm this expectation, except in the case of Group As for Examination II. For some reason As made a very poor showing in this test at that time as compared with what should be expected. Why this should have been is unaccountable to the writer.

2. **Calculation test.**—This test is one that is recommended by Woodworth and Wells in their monograph on Association Tests*, and is called by them the "constant increment" test. They state that it is "a little-recognized method, but

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* R. S. Woodworth and F. L. Wells, "Association Tests," *Psychol. Rev. Monog.*, No. 57, 1911, p. 46. See also H. L. Hollingworth, "The Influence of Caffeine on Efficiency," *Arch. of Psychol.*, No. 22, 1912, pp. 89–102, for an extended use of this method.

one which in direct comparison has shown superiority over other forms." It consists in presenting to the subject a series of two-place numbers and requiring that 4 be added to each of the numbers and the answer called out. The blank proposed by Woodworth and Wells was not employed as being too long for our purposes and instead four series of ten numbers each were substituted for it.*

After a great deal of manipulation the four sets were made practically equal in difficulty. The sets were designated by the letters A, B, C and D, and were always used in that order.

The children were very carefully instructed as to just what was expected of them in this test, and then they were given a "trial test" to see if they really understood. In order to make doubly sure that they did thoroughly understand the requirements of the test, no account was taken in the final results of the first set, *i. e.*, A. The final results are based then on the average obtained from the three sets, B, C and D.

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* The four series were as follows:

List A	List B	List C	List D
34	65	57	33
56	38	42	52
39	61	35	45
55	46	60	58
68	32	53	37
50	54	36	66
41	40	51	44
62	67	69	30
47	43	48	49
63	59	64	31

The actual procedure consisted in giving to the child the list face down, typewritten on a card 5 x 2 inches. The signals "Get ready," and then "Go," were given. At the latter signal the child turned the card over in his hand and commenced adding. At the same time the stop-watch was started.

All mistakes not corrected by the child were penalized by adding one-tenth of the total time of that list to the total time. This seemed as fair a method as any, as it took about as long to correct a mistake, when it was seen by the child, as to do the original addition. In fact, if anything, the penalty is too little. In a few cases the final result of a child is based on but two sets instead of three. These were cases where the child had been noticeably interrupted during the addition as, for example, by a fly, or a passer-by, etc.

The medians in Table III show a very great difference in proficiency for the various groups in this test. Group As is unmistakably best, Cs second, Ds third, and Bs last. The same order still holds good when the data from Examination III are considered. With one exception, the differences between the groups in either test are much greater than the probable error, representing real differences in ability. This single exception is in the case of Cs and Ds in Examination II. The extremely high probable error of Ds makes it seem as though the difference between

TABLE III

Calculation Test. Giving the Average Time in Seconds for Three Sets of Ten Additions

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group																
Medians......	18	38.2	28.7	9.5	27	46.3	36.4	9.9	17	48.7	38.8	9.9	9	68.5	52.4	16.1
P. E. of Med..		*2.9*	*2.1*			*3.9*	*2.4*			*5.0*	*6.2*			*2.6*	*2.8*	
Sub-Groups																
M 10.1– 25.0	1	20.7	16.7		2	23.9	20.25									
N 25.1– 40.0	10	31.85	25.99		6	36.38	33.23		5	30.78	26.36		1	32.6	27.5	
O 40.1– 55.0	4	49.68	34.33		9	45.96	35.63		6	44.03	39.25		1	40.8	33.9	
P 55.1– 70.0	2	63.75	43.1		2	59.75	43.65		1	59.2	38.8		3	63.63	43.7	
Q 70.1– 85.0	1	72.9	55.8		2	75.1	60.2		1	78.6	81.6		3	76.5	54.0	
R 85.1–100.0					2	87.9	83.95									
S 100.1–115.0													1	110.7	72.6	
T 115.1–130.0					1	115.1	F.									
U 130.1–145.0					1	131.1	55.7		1	143.0	79.8					
Failure.......					2	F.	62.2		3	F.	F.					
Av. N, O, P, Q.		54.54	39.81	14.73		54.30	43.18	11.12		53.15	46.50	6.65		53.38	39.78	13.60
% Gain......				*27.0*				*20.5*				*12.5*				*25.5*
Ratio of Gain.				100				76				46				95

Cs and Ds might be due to chance, but when it is realized that this high probable error is caused by very poor performance on the part of a number of children in Ds this seeming overlapping becomes actually very improbable. It is interesting to note that Bs in Examination III reaches the proficiency of Ds in Examination II, and, likewise, Ds reaches Cs's first performance, and Cs surpasses a trifle As's first performance.

Evidently from Table III Group As has gained the most (27.0%), with Bs (25.5%) second, Group Cs is third (20.5%), and Group Ds fourth (12.5%). If one poor record in Ds is, however, omitted, Ds makes just exactly as good a showing as Cs.

The above statement as to the amount of improvement shown by the various groups is the best and most accurate that can be made. But in the case of this calculation test, possibly more than in the case of any of the other tests, there enters another factor which influences the amount of improvement shown in our data for the various groups. This factor is the amount of practice in the performance prior to the test. In the learning of any task the individual makes very great gain at the start and as he becomes more and more proficient his gain in rate of performance becomes smaller and smaller. Hence a very bright boy might on his third trial perform a task in the same time that a duller boy would do it on his tenth trial. Now, when they repeat the task, the first boy will perform his fourth trial in quicker time than the second will do his eleventh trial. The same holds true in this test: the children who have been the most drilled will make the smallest gains with one trial more. Group As should make smaller gains than Cs, Ds, or Bs, because it is composed of children who have had more drill in arithmetic than the other groups. Of the last three, Ds contains the largest proportion of children of little education and so should make the largest gain. This factor of the amount of practice is not guarded against in our "equal-group" method. For in this method we compare improvement as based on equal initial performance. But when one group, as, for example, As, has had a large amount of drill and another group, say Ds, has had only a little, then we are comparing brighter children naturally in Ds with the duller children in As. And the brighter children with little practice ought to gain more from another trial than duller children with a large amount of practice. That As has shown up so well in comparison with Cs, Ds, and Bs is truly surprising, and that Ds, which theoretically should gain most, has gained least, makes its poor showing still more prominent. However, taking the groups as they are and as we found them, we shall have to abide by the results of Table III.

Conclusion.—(1) The control group is the most proficient in the calculation, requiring but 38.2 seconds, for which the treated children took 47.5 seconds and the non-treated 68.5 seconds. In Examination III the controls did the adding in 28.7 seconds, the treated in 37.6 seconds and the non-treated in 52.4 seconds. Of the treated children, the completely cured surpassed the incompletely cured.

(2) The controls gained the most (27.0%), the non-treated next (25.5%), and the treated children next (16.5%). But the completely cured gained 20.5% to the incompletely cured children's 12.5%.

3. **Logical memory.**—Two stories of 100 words each and of approximately equal difficulty of thought were selected. An earlier form of the second story was tested out, together with the first story, in one of the grammar schools of New York City upon third-grade children by Miss Katherine Hart, and found to be more difficult. Changes were then made in the light of this test, so that the story as used would be practically as difficult as the first story.*

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* The two stories were as follows:

I

A man was driving along a country road when the back wheels of his wagon suddenly sank in a rut. He got down from his seat and looked at the wheels but did nothing except call loudly for help. Finally a farmer came across the fields to see what was the trouble. He looked at the accident but did not offer to help. "Put your shoulder to the

The children were instructed to read the story aloud and it was emphasized to them that after they had read the story they would be required to write down what they could remember of it. They were told to reproduce the story, using the same words as far as they were able, but when they could not do this they were to use their own words. They were allowed five minutes. Only a few did not finish in this time and they were among those who made the best scores. Lack of ability in writing did not then prevent the poorer children from telling all they could in the five minutes. Those children who could not write were allowed to dictate to the experimenter what they remembered of the story. It was, of course, jotted down just as they gave it. In some cases considerable urging had to be done to keep them at the work. But care was taken not to aid them through suggestive questions or remarks.

The method of scoring was based on Hender-

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wheel," he said, "and whip up your horses and you will get clear." He then went back and left the driver, who tugged and pushed until he got free and drove away.

II

A woman was cooking in her kitchen when her little boy came in and began talking to her. "Don't bother me," she said; "I'm busy now." He stood still for a minute and watched her as she peeled potatoes and put them in the kettle. Then he begged for something to eat. His mother said he must wait till supper time, but he reached over and took some cake. His mother caught his arm, but he pulled away and ran outside. She started to follow, but just then the kettle boiled over and she had to let him go.

son's* system of breaking the story up into its "details" or ideas and counting the number of these that were reproduced in each of the children's accounts. Actually the method was a compromise between using *details* and simple *words* as the unit of measurement. For, as it was being graded, the first story seemingly broke up into different units from those arbitrarily chosen at first. Afterwards the stories were regraded in the light of these natural units (natural at least to me) and these second scores are used here. Full credit was given if the actual words were reproduced and half credit for substitutions. Incorrect details which really vitiated the point of the story were correspondingly scored against, but those that could easily have been given as substitutes were not counted one way or the other. Actually, there were only a few such incorrect details to the first story and none in the second. As the second story had been composed so as to include similar elements to those in the first story (such as a direct quotation, a clause not bearing on the main development of the story, etc.) it was easily broken up into units corresponding to those in the first story. These units were, of course, used as the basis of grading papers in the second test. The final scores are stated as per cents. or, in other words, on a basis of 100.

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* E. N. Henderson, "A Study of Memory for Connected Train of Thought," *Psychol. Rev. Monog.*, No. 23, 1903.

The medians in Examination II of Table IV indicate that Groups As and Cs are equal (31.5 and 32.0); Bs is next (28.0), and Ds last (19.0). In Examination III the order of superiority of the groups remains the same, except that now As is considerably superior to Cs. The gains in performance are As, 21%; Cs, 10%; Ds, 12.0%, and Bs, 4.0%.

Turning now to the second part of this table to note the relative gains of these various groups when our "equal-group" method is used, we find that As has gained 16.0 points (54.5% on its first score), Cs, 11.4 points (36.5%); Ds, 5.5 points (18.1%), and Bs, 4.7 points (14.4%).

Conclusion.—(1) In Examination II the Controls scored 31.5, the treated children 25.5, and the non-treated 28.0. In Examination III the Controls scored 52.5, the treated 36.5, and the non-treated 32.0. The completely cured children were in both tests superior to the non-treated, but the incompletely cured were inferior to that group.

(2) The Controls gained 54.5%, the treated 29.4, and the non-treated but 14.4%.

This test gives us one of the clearest proofs of the value of treating hookworm children that we have in the whole study. The treated children have gained more than twice as much as the non-treated.

TABLE IV
Logical Memory. Expressed in Terms of Per cent. of a Correct Reproduction of a Story of 100 Words

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group																
Medians.......	18	31.5	52.5	21.0	27	32.0	42.0	10.0	17	19.0	31.0	12.0	9	28.0	32.0	4.0
P. E. of Med...		*2.6*	*3.0*			*2.3*	*2.2*			*2.3*	*2.4*			*4.8*	*3.5*	
Sub-Groups																
M 70– 61	1	64.0	62.0													
N 60– 51	3	53.7	75.3		1	52.0	68.0		1	54.0	44.0					
O 50– 41	2	43.0	60.0		7	45.6	49.6		1	44.0	50.0		1	44.0	40.0	
P 40– 31	4	34.0	46.3		9	33.8	38.4		4	36.0	39.8		3	36.7	42.3	
Q 30– 21	5	25.4	43.4		3	28.7	57.7		2	24.0	28.0		1	28.0	41.0	
R 20– 11	3	14.7	31.3		6	16.5	24.5		6	16.3	24.3		1	20.0	24.0	
S 10– 1					1	5.0	45.0		3	9.0	17.7		3	7.3	13.3	
Av. O, P, Q, R.	14	29.28	45.25	15.97	25	31.15	42.55	11.40	13	30.08	35.53	5.45	6	32.18	36.83	4.65
% Gain......				*54.5*				*36.6*				*18.1*				*14.4*
Ratio of Gain.				100				67				33				27

4. **Memory span.**—This is the familiar memory span test, using digits for material. The procedure as set forth in Whipple's "Manual of Physical and Mental Tests" (page 362) was followed throughout, except that no metronome was employed. The series was repeated by the child immediately after the presentation and the result jotted down by the experimenter. Three series of digits were presented for each length. The testing was considered complete when three successes with one length of series had been obtained and three failures with a longer series, together with the appropriate intermediate trials, e. g., all correct with 5 digits, 1 correct with 6 digits, and 0 correct with 7 digits equals a score of 6 digits. The subject's memory span was estimated as the maximum number of digits that he could once reproduce without an error out of three trials for each length. The writer heartily agrees with the established custom of using a metronome in a careful study of memory span. But in field work the presence of a metronome would only add one more to the already too many distractions which the experimenter has to meet. A swinging pendulum might have been used, but it would have encumbered the party and would have been troublesome to use in many of the places where we were forced to give tests—such as on the porch of homes, etc. To the extent that the absence of a metronome vitiates

the results our *actual* group results are faulty (see Table V), but the *relative* group results, the main object of this experiment, are not injured, as the above possible error would appear equally often in both tests and would affect the results of both tests in the same way.

Table V presents the median memory span for each group at each examination, together with the probable error of these medians. In the following little table are given the per cent. of subjects in each group who had memory span of (a) 5 or less, (b) 6, and (c) 7 or more:

Groups	PER CENT. OF SUBJECTS WITH SPANS EQUAL TO					
	5 or less		6		7 or more	
	Exam. II	Exam. III	Exam. II	Exam. III	Exam. II	Exam. III
A	20	13	47	47	33	40
C	36	28	36	44	28	28
D	21	36	57	36	21	29
B	38	38	25	38	38	25

A study of these data shows very clearly that Group As is superior to the other groups. This is all the more noticeable when both the percent of subjects having large spans and the percent having small spans are taken into consideration. No particular difference is to be noted between Groups Cs, Ds and Bs.

Turning again to Table V we see that of the

TABLE V
Memory Span

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group																
Median.......	18	6.3	6.3	0	26*	5.9	6.0	0.1	17	6.0	5.9	−0.1	9	6.0	5.9	−0.1
P. E. of Med.		*0.2*	*0.2*			*0.2*	*0.1*			*0.1*	*0.1*			*0.3*	*0.3*	
Sub-Groups																
M 8	2	8.0	8.0		1	8.0	6.0		2	8.0	7.0		1	8.0	7.0	
N 7	5	7.0	7.6		7	7.0	6.7		2	7.0	7.5		2	7.0	6.5	
O 6	8	6.0	6.13		9	6.0	6.44		9	6.0	5.78		3	6.0	5.33	
P 5	3	5.0	5.2		6	5.0	5.5		3	5.0	5.2		3	5.0	5.0	
Q 4					2	4.0	5.0		1	4.0	6.0					
R 3					1	3.0	4.0									
Av. N, O, P,†.	16	6.0	6.31	0.31	22	6.0	6.22	0.22	14	6.0	6.16	0.16	8	6.0	5.61	−0.39
Av. M, N, O, P.	18	6.5	6.73	0.23	23	6.5	6.16	−0.34	16	6.5	6.37	−0.13	9	6.5	5.96	−0.54
% Gain N,O,P.				*5.2*				*3.7*				*2.7*				*−6.5*
Ratio of Gain.				100				71				52				

* Case No. 361 not tested in Exam. II.

† Because of the few cases in sub-group M, an average on the basis of N, O, P seems more valid than one based on M, N, O, P, and has consequently been used. The data for M, N, O, P are also given. The only real difference between the two sets of averages is in the case of Group C. There the average of N, O, P is certainly the fairer measure. For another reason for using N, O, P, instead of M, N, O, P, see pages 38 and 39.

Groups As, Cs, Ds and Bs, when they are compared on the basis of their showing in sub-groups M, N, O and P, Group As gained 0.23 of a span, Cs lost 0.34 of a span, Ds lost 0.13, and Bs 0.54. Stated in percentage, As gained 3.5%, Cs lost 5.2%, Ds lost 2.0% and Bs 8.3%. But as sub-group M is composed of only one or two subjects in any of the groups, a comparison of the groups on the basis of sub-groups N, O and P is fairer. (See also page 38 for another very good reason why data based on sub-groups N, O and P are more reliable than that based on sub-groups M, N, O and P.) On such a basis Group As gained 0.31 of a span (5.2%); Cs 0.22 of a span (3.7%); Ds 0.16 of a span (2.7%), and Bs lost 0.39 of a span (−6.5%). The only difference in the methods of comparing the groups, relatively speaking, is to change a large difference between As and Cs to a small difference (8.7% to 1.5%). As the second method seems fairest to all the data, it has been adopted.

Conclusion.—(1) The controls (As) are superior to the other three groups, while the latter (Cs, Ds and Bs) are practically equal in ability in this trait.

(2) The normal subjects (As) gained 5.2%, the treated hookworm children gained 3.2%, while the non-treated lost 6.5%. The completely cured gained more than the incompletely cured (3.7% as compared to 2.7%).

5. **Handwriting.**—After the children had read aloud a story of 100 words they were directed to write down as much of it as they could remember. No reference was made in any way to the fact that their handwriting would be considered. Consequently our ratings are based on the ordinary handwriting of these children and not on a passage assigned to them for writing.

After the second examination the present writer graded each specimen of handwriting, using Thorndike's scale for handwriting of children in Grades 5 to 8.* Some time later he graded them again without reference to the first grading. His wife also graded them independently of him. After Examination III the new specimens were also graded twice by the writer and once by his wife. A fourth grading was then made by the writer's sister, Miss A. Louise Strong. In this case, to guard against practice or fatigue effects, the specimens of a group from Examination II and then Examination III were rated, then the specimens of a second group were so treated, etc., until all were rated. During this work Miss Strong had no knowledge of the previous work done by the writer or his wife, nor did she compare any of her ratings until all through the task. A comparison of the average of the first three ratings with an average of the four ratings shows scarcely a case in which the difference between the two is more than 0.3 of a grade. It would seem, then, that these four ratings are sufficient to guard against personal biases on the part of those who are doing the grading. There is, however, one error present in this statement, but it does not affect the relative gain of Examination III over Examination II for the several groups, but only the actual gain. This is, that the writer felt after grading the specimens of handwriting in Examination II, that he had been too lenient and had graded many too high. He was conscious of this attitude and tried to overcome it in grading the specimens from the third examination. A comparison between his two sets of ratings, together with a comparison of his ratings with those of the other two judges, reveals the fact that he was more critical with the third examination than he had been with the second. The final averages for the two tests are based consequently on two factors: (1) the actual handwritings of the children, and (2) the attitude of the judges at the time of rating them. Because the figures indicate, then, that the second set of handwritings was poorer than the first set, we cannot be sure that this is actually the case—the difference may be entirely due to a difference in the mental attitude of the judges on the two occasions. But, as already stated, this difficulty does not affect the purpose of the test, which is a determination of the relative improvements of the several groups after treatment.

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* E. L. Thorndike, "Handwriting," *Teachers College Record*, XI, 2, 1910.

According to Table VI the normal children are the best writers, the completely cured are next, the non-treated are next, and the incompletely cured the poorest—and decidedly the poorest. The same order holds for the second test as for the first, but here there is a more decided difference between the normal children and the hookworm children.

Groups As and Cs have apparently been the only groups to improve, but we must bear in mind what had already been said, that probably the standard of grading has been raised somewhat. Group Bs lost 9.8% and Ds 10.9%. Here again the order of ability at the start is the same as the order of improvement of the various groups.

Conclusion.—(1) The control squad is rated 9.2, the non-treated hookworm children 8.8, and the treated children 8.1. The completely cured are 0.2 of a grade inferior to the non-treated, while the incompletely cured are 1.2 inferior. At the time of Examination III the controls are rated 8.9, the non-treated 8.0, and the treated 8.0. The non-treated have thus lost the superiority over the treated children which they had at the start.

(2) The controls gained 1.2%, the treated lost 4.7%, and the non-treated lost 9.8%. But the

TABLE VI

Handwriting. Graded According to Thorndike's Scale of Handwriting

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group																
Medians......	18	9.2	8.9	−0.3	27	8.6	8.5	−0.1	17	7.6	7.4	−0.2	8*	8.8	8.0	−0.8
P. E. of Med..		*0.2*	*0.2*			*0.2*	*0.2*			*0.2*	*0.2*			*0.2*	*0.3*	
Sub-Groups																
M 13– 12.1																
N 12– 11.1					2	11.35	10.95		1	11.1	9.0					
O 11– 10.1	6	10.53	9.53		1	10.6	9.3		2	10.7	9.3					
P 10– 9.1	3	9.57	9.57		6	9.4	9.1		1	9.3	7.3		3	9.2	9.03	
Q 9– 8.1	6	8.72	8.18		9	8.63	8.83		3	8.43	7.57		3	8.53	7.87	
R 8– 7.1	2	7.35	8.2		3	7.5	8.03		6	7.45	7.55		2	7.45	5.8	
S 7– 6.1	1	6.4	8.0		4	6.38	6.63									
T 6– 5.1									1	5.9	6.0					
U Failure.					2	F.	F.		3	F.	F.		1	F.	F.	
Av. P, Q, R..	11	8.55	8.65	0.10	18	8.51	8.65	0.14	10	8.39	7.47	−0.92	8	8.39	7.57	−0.82
Gain %......				*1.2*				*1.6*				*−10.9*				*−9.8*
Ratio of Gain.				100				133								

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* Case No. 433 received a score of 8.3 in Exam. II; in Exam. III the subject said he couldn't write and was allowed to dictate the story. Hence the record is omitted.

slight loss shown by the two treated groups is due entirely to Group Cs, as Group Ds actually lost more than Group Bs.

6. The form-board test.—This test is the familiar one used so much in the study of subnormal children. The particular form used was that known as Goddard's* form-board as distinguished from boards used by other investigators. The test consisted of seeing how quickly the child could place the ten blocks in their appropriate holes. The child was thoroughly instructed as to what was required of him, and told that we wanted to see how quickly he could perform the test. Three trials were made in succession and the best time used as the measure of ability.

From Table VII we learn that Group As performed the task in 16.1 secs., Cs in 19.0 secs., Ds in 20.0 secs., and Bs in 20.2 secs. in Examination II, and they maintained the same order of superiority in Examination III, decreasing their time of performance by about 2 secs. Goddard (1912, p. 51) gives an age equivalent for time of performance in this test, as based on a study of 271 normal children. From his table we should have the following mental ages for our four groups as given in Table VIII.

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* See H. H. Goddard, "The Form Board as a Measure of Intellectual Development," *Training School*, 1912, IX, 49–51, and C. H. Stoelting's Catalogue of Apparatus, where it is listed as No. 77552-b.

TABLE VII

Form-Board Test. Expressed in Seconds, Representing the Total Time Consumed in Performing the Best Trial Out of Three

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group																
Medians......	18	16.1	14.3	1.8	27	19.0	17.2	1.8	16*	20.0	18.4	1.6	9	20.2	18.0	2.2
P. E. of Med..		*0.6*	*0.5*			*0.5*	*0.4*			*0.7*	*0.6*			*0.8*	*0.5*	
Sub-Groups																
N 13.1– 15.0	6	14.07	13.50		4	14.60	15.30						1	14.40	12.60	
O 15.1– 17.0	5	15.88	14.20		4	17.00	17.25		3	16.47	14.80		2	16.00	14.20	
P 17.1– 19.0	1	17.60	16.60		6	18.30	16.60		2	18.20	19.30		1	18.20	17.40	
Q 19.1– 21.0	5	20.12	17.08		6	20.23	16.90		5	19.92	17.88		4	20.65	18.80	
R 21.1– 23.0	1	22.20	17.40		4	22.25	19.50		1	21.20	17.60					
S 23.1– 25.0									2	23.80	20.60					
T 25.1– 27.0					2	26.10	20.10		1	26.00	20.00					
U 27.1– 29.0					1	28.40	20.60		1	27.40	29.00		1	29.00	20.60	
V 29.1– 31.0																
W 31.1– 33.0									1	31.80	21.00					
Av. N, O, P, Q.	17	16.92	15.35	1.57	20	17.53	16.51	1.02					8	17.31	15.75	1.56
Av. O, P, Q, R.	12	18.95	16.32	2.63	20	19.45	17.56	1.89	11	18.95	17.40	1.55				
% Gain N, O, P, Q.......				*9.3*				*5.8*		(Estimated)		*5.2*				*9.0*
Ratio of Gain.				100				62				56				97

* Case No. 464 was overlooked in Exam. II.

TABLE VIII

A comparison between the results obtained from the Form-Board Test and the Binet-Simon Test. (The results from the former have been stated in terms of mental years, according to Goddard's table.)

Group	BASED ON FORM-BOARD		BASED ON BINET-SIMON TESTS	
	Exam. II	Exam. III	Exam. II	Exam. III
As	10.7	12.0	10.1	10.3
Cs	9.1	9.8	9.6	9.5
Ds	8.5	9.3	9.2	9.7
Bs	8.3	9.5	9.4	10.4

The mental ages as obtained by these two tests do not agree so very well. As is rated 0.6 yr. too high by the Form-Board Test as compared with the Binet-Simon Test, while Cs, Ds and Bs are rated too low (respectively 0.5, 0.7 and 1.1 yrs.). In Examination III the differences are still greater for Group As (1.7 yrs.), but less for Groups Cs, Ds and Bs (respectively 0.3, 0.4 and 0.9 yrs.). Nevertheless, as a rough approximation, Goddard's scale is surprisingly worth while.

On turning again to Table VII to study the relative improvement made by the several groups, we find that As gained 9.3%, Bs 9.0%, Cs 5.8%, and Ds but 5.2%.

With the exception of Group Bs, the order of improvement here is the same as the order of ability of performance given in the paragraph above. The best have gained the most and the poorest the least. Group Bs, however, makes a very creditable gain.

Conclusion.—(1) The control squad performed the test in 16.1 secs., the treated children in 19.5 secs., and the non-treated in 20.2 secs. Hookworm disease, with its accompanying factors, reduces the speed in this test 4–5 seconds. And after the treatment the difference is still practically the same.

(2) The control squads gained 9.3% in performance, the non-treated 9.0%, and the treated children but 5.5%.

7. The Binet-Simon test.—Goddard's * revision of the Binet-Simon Scale and adaptation to American children was followed throughout in our tests. In Examination II, Goddard's "Record Blank for Revised Binet Test" was used with only two changes. These were due to the local environment of the southern children. In Test X 5 and XI 2 local names of places were used instead of "Philadelphia," and the word "railroad" instead of "river." And in Test XII 5, the test question, "I saw a crowd going along the road. They were all dressed up and each had a basket or a bundle. Where were they going?" was used instead of the sentence dealing with "my neighbor's visitors." In Examination III a modification of this blank was employed—the modifications being simple changes in some of the questions, as suggested by Goddard,* in order to prevent the children from answering from memory. The changes were as follows:

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* See H. H. Goddard, "The Binet-Simon Measuring Scale for Intelligence," *Training School*, January, 1910. Also by same author, "Two Thousand Normal Children Measured by the Binet-Simon Measuring Scale of Intelligence," *Ped. Sem.*, XVIII, June, 1911, 232–259, and "Standard Method for Giving the Binet Test," *Training School*, X, 1913, 23–30.

V 3. The sentence "Little Mary likes to play with her dolls" was used.

VI 2. Required to define "spoon," "bed," "dresser," "cow," "father."

VIII 1. Required to compare from memory the three pairs: "horse-cow," "stone-egg," "grass-tree."

X 4. The following sentences were used to test comprehension:

I. a. What ought one to do when he is sleepy?

b. When he sees that it is raining just as he is about to go for a walk?

c. When one is tired and a long way from home?

II. a. What should one do to get a watch that he wants at a store?

b. What should one do when some one has offended him and comes and asks pardon?

c. What happens when two persons discuss a question without understanding the words?

d. What ought one to do when he has received punishment that he did not deserve?

e. What should you do when a person always contradicts you, no matter what you say?

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* "The Binet-Simon Measuring Scale for Intelligence," *op. cit.*

X 5 and XI 2. The three words, "play," "rain" and "ball," were used.

XI 1. These sentences were used:

a. A man came to see Mr. Jones. Mr. Jones was not at home. I asked him his name. He said, "Oh, it is not necessary to leave my name; Mr. Jones knows me."

b. I received a letter from a friend in which he said: "If you don't get this letter, just let me know and I'll write again."

c. I read in a paper that they fired two shots at a man. The first shot killed him, but the second didn't.

d. The judge said to the prisoner: "You are to be hanged, and I hope it will be a warning to you."

e. An unfortunate bicycle rider has had his head broken and is dead from the fall; they have taken him to the hospital and they do not think he will recover.

XI 4. The three words used were "man," "toy," and "cold."

XI 5. The sentences were:

DAY IT WE PICNIC THE OUR RAINED HAD.

IF ASKED BALL MY HAVE WE MOTHER PLAY I MAY.

A MAKES BOY GOOD HIS HAPPY MOTHER.

XII 2. The three words to be defined were: "truth," "mercy," and "pity."

XII 3. The sentence to be repeated was: "Mary is often praised for her very nice, neat work. She is always a good little girl, and likes to sew."

The writer feels that all the changes made were proper and in no way injured the validity of the second test as compared with the first test, except the change in X 5 and XI 2. The three words, "Play," "Rain," "Ball," should not have been employed, for "Play" and "Ball" become actually but one idea instead of two, and the total task is but to put two ideas together in a sentence instead of three. However, a study of the individual scores does not show that the revised test was much easier than the original, and the final results do not seem to be affected by this oversight.

TABLE IX

Distribution of differences between actual age and mental age. The Per Cent. of each Group is shown in each of the one-year divisions. The average age, both actual and mental, is also given, together with the Gain made in Examination III over Examination II.

Groups	As		Cs		Ds		Bs	
Exam.	II	III	II	III	II	III	II	III
1.9 to 1.0	6							
0.9 0	17	17	4	8	6	6	11	22
−0.1 −1.0	33	28	27	23	0	24	22	33
−1.1 −2.0	33	33	31	27	47	24	56	44
−2.1 −3.0	6	17	35	42	29	24	11	
−3.1 −4.0	6	6	4		12	18		
−4.1 −5.0					6	6		
No. of Cases	18	18	26	26	17	17	9	9
Av. Act. Age	11.1	11.4	10.9	11.2	11.1	11.4	10.6	10.9
Av. Men. Age	10.1	10.2	9.3	9.6	8.9	9.4	9.4	10.0
Gain, Act. Age		0.3		0.3		0.3		0.3
Gain, Men. Age		0.1		0.3		0.5		0.6
Diff. Act. and Mental Age	−1.0	−1.2	−1.6	−1.6	−2.2	−2.0	−1.2	−0.9

Table IX presents considerable data obtained from the Binet tests. It gives, first of all, the distribution of the subjects according as they were mentally above their actual age or below that age, and the number of years above or below. Thus of the 18 subjects in Group As, 6% were mentally about a year and a half above their actual age, 17% were about half a year above, 33% were about half a year below, 33% were about a year and half below, 6% two and a half years below, and 6% three and a half years below. The average actual age of this group was 11.1 years, while its mental age was 10.1 years. The group, as a whole, was just one year behind mentally. The non-treated hookworm children (Group Bs) were mentally 1.2 years behind their actual age. The children who were later cured of the hookworm disease (Group Cs) were 1.6 years behind, while the children who were later only partially cured (Group Ds) were 2.2 years behind. Group Cs was, then, 0.5 year behind the normal children in the same neighborhood, and Group Ds was 1.4 years behind.

It is very evident from these figures that the non-treated hookworm children (Group Bs) were not so much retarded to start with as were the hookworm children who were later treated. Information derived from other tables confirms this point, but we will defer its consideration to a later section. This means, in other words, that the non-treated children were not in so serious a condition to start with as were the treated children.

But to return to Table IX. After the 0.3 year interval, Examination III showed that the control squad (As) had gained 0.1 year mentally instead of 0.3, as was to be expected, while the completely cured group (Cs) had gained 0.3 year, and the incompletely cured group had gained 0.5 year. But the non-treated gained the most of all, *i. e.*, 0.6 year. These results are based on the averages of the various groups. When the medians are studied (see Table X) a somewhat different picture is presented. Group As now gains 0.2 year, Cs loses 0.1 year, Ds gains 0.5 year and Bs 1.0 year. Evidently from these two sets of measurements the non-treated group have gained the most, the incompletely cured next, while the completely cured and the control squad have actually dropped behind when the actual ages are taken into consideration. But, in order to obtain a perfectly fair comparison between the different groups, it is necessary to employ our modified form of "equal groups" method, as previously pointed out. Table X gives us this information. When we compare the children in sub-groups N, O, P, we find that Group As gained 0.2 years, Group Cs 0.2 years, while Group Ds gained 0.5 years and Group Bs 0.5 years. All three methods of comparing the data, then, agree in that the first two groups gained less than what should be expected, while the group that was incompletely cured and the non-treated group gained more than once and a half what was to be expected.

Seemingly, the control children are a year behind where they should be mentally and are developing at a slower rate than normal. No effect from the treatment can be seen in Group Cs, but in Group Ds, which was made up largely of severe cases who were not completely cured, we find a decided gain in mental age—a gain nearly twice that to be expected from normal children. However, as the non-treated group also gained more than what would be normally expected, we cannot attribute the above large gain to the treatment, especially as the completely cured did not gain as much as should normally be expected from them.*

One would seemingly have the right to read from the figures in Table X the fact that children with the hookworm disease fall considerably behind children without the disease, and that the more severe the attack the more do such children

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* Data obtained by the writer on 23 boys between the ages of 9.9 and 12.0 in the Horace Mann School (New York City), at the same time as the above tests were given, showed an average actual age of 11.1 years and an average mental age of 11.0 years. This group gained 0.2 years if the averages are considered, 0.1 year if the medians are considered, and 5.5% if the "equal-group" method is used. Because of this information, the writer feels the statements above represent just the condition they picture. He is not unmindful, however, of the results of many investigators, as, for example, Jean Weidensall, "Psychological Tests as Applied to Criminal Women," *Psychol. Rev.*, 1914, XXI, 370–375, which go to show that mental ages over 10, or possibly 10.5 years, cannot be accurately determined by the Binet-Simon Scale, a view in which he heartily concurs.

TABLE X

Mental Age as Determined by the Binet-Simon Measuring Scale

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group																
Medians......	18	10.1	10.3	0.2	26*	9.6	9.5	—0.1	17	9.2	9.7	0.5	9	9.4	10.4	1.0
P. E. of Med.		*0.2*	*0.1*			*0.2*	*0.2*			*0.3*	*0.2*			*0.1*	*0.2*	
Sub-Groups																
M 12– 11.1	3	11.33	11.1													
N 11– 10.1	6	10.60	10.75		8	10.44	10.71		3	10.33	10.93		2	10.60	10.65	
O 10– 9.1	7	9.63	9.74		8	9.75	9.86		6	9.77	10.08		3	9.53	10.03	
P 9– 8.1	2	8.60	8.90		4	8.70	8.98		4	8.20	8.80		4	8.60	9.68	
Q 8– 7.1					5	7.70	8.48		3	7.53	7.83					
R 7– 6.1					1	7.00	7.40									
S 6– 5.1									1	6.00	7.20					
Av. N, O, P..	15	9.61	9.80	0.19	20	9.63	9.85	0.22	13	9.43	9.94	0.51	9	9.58	10.12	0.54
Gain %......				*2.0*				*2.3*				*5.4*				*5.6*
Ratio Gain...				100				115				270				280

* Case No. 361 not tested in Exam. II.

fall behind in the mental life. Undoubtedly this is the case, and there seems little doubt that considerable of the difference shown in the above figures is due to hookworm disease and to that alone. But just how much of the difference can be ascribed to the disease and how much is due to differences in environment and heredity cannot be answered. As has already been pointed out, *all* the children between the ages of 10 and 12 years in six schools were examined. The children attending these six schools were all of the same general hereditary stock, but they did not come from homes of equal economic standing. The city school contained children who, from dress and behavior, were very much superior to the children in the country schools. And among the country schools there was a marked difference. The dress of those in B* and D was very noticeably poorer than that of the children in the other schools. And it was at B and D that we found our worst conditions. We might roughly divide the schools into three grades as to the economic (and probably hereditary) conditions of the children. The first grade would be that of A; the second, that of C and E; and third, that of G, D and B. The difference between the first and second grades is much greater than that between the second and third grades. With this difference in the economic conditions of the children in the different schools in mind, notice that:

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* The six schools are referred to here by the first six letters of the alphabet.

Group As is composed of 17 children from School A and 1 from School E.

Group Cs is composed of 11 children from A and 6 from C, 6 from E, and 4 from B.

Group Ds is composed of 2 children from A, 6 from C, 4 from E, and 5 from B.

Group Bs is composed of 3 from A, 1 from E, 3 from G, and 2 from B.

Stated in another way:

Group As: 94% from Best Grade of Homes, 6% from Intermediate, 0% from Poorest.

Group Cs: 41% from Best Grade of Homes, 44% from Intermediate, 15% from Poorest.

Group Ds: 12% from Best Grade of Homes, 59% from Intermediate, 29% from Poorest.

Group Bs: 33% from Best Grade of Homes, 11% from Intermediate, 56% from Poorest.

In other words, 94% of the control squad, 41% of Group Cs, and 12% of Group Ds come from the best economic environment and, on the other hand, 0% of Group As, 15% of Group Cs, and 29% of Group Ds comes from the poorest economic environment. The difference in the mentality of Groups As, Cs and Ds shown in Table IX cannot, then, be ascribed to the hookworm disease alone. There are other and conflicting factors that enter into the general cause of these differences.

Conclusion.—The Binet-Simon tests show very clearly that the various groups of children are not equal in mental ability, although they are of the same actual age. The normal children (Group As) and the non-treated children (Group Bs) are about one year behind where they should be. The hookworm children who had relatively light cases and were completely cured are a year and a half behind mentally, while the hookworm children who had severe cases and were not cured, are two years behind. At first glance one is tempted to ascribe all the differences between mental age in the several groups to the presence or absence of hookworm disease. But when the data concerning the economic condition of the homes of these children are studied, it is apparent that the differences in mental age might be ascribed to this condition also. The economic condition of the home does reflect, certainly, to some extent the hereditary abilities of the families. But in a rural community with a disease such as hookworm on hand, it is not safe to declare that ability of the parents correlates extremely high with their economic conditions. The character of the disease is such as to enervate its victim, so that the economic condition of the family may be due just as much to the hookworm history of the parents and grandparents as to the innate mental ability transmitted by their germ plasm.

We face here one of those particularly exasperating situations in which it seems well-nigh impossible to separate out the distinct factors of heredity and environment. The best that can be done is to weigh all the details of our study and express our opinion as to how each of these two fundamental factors does enter into the problem. When we do this we reach the conclusion that the differences in mental ability shown by the different groups of children are, without doubt, due to both factors, *i. e.*, heredity and environment. The first factor shows itself, among other ways, in differences in the economic condition of the families of these children. These differences result in varying intensities of hookworm infection, since it is a fact that the poorer the family the greater likelihood there will be for infection. The second factor affects the mental development of the children in various ways, chief among which is the varying likelihood of hookworm infection.

The results from the Binet-Simon tests do not agree with those from the other tests as to the amount of mental improvement which has taken place during the interval between the second and third examinations. The control group (As) has developed 0.2 of a year mentally during a period of 0.3 years. The completely cured group (Cs) has gained a like amount. The incompletely cured group (Ds) and the non-treated have gained 0.5 year in the same time.

COMPARISON BETWEEN THE CHILDREN BETWEEN 10 AND 12 YEARS OF AGE (GROUP DS) AND THE CHILDREN BETWEEN 12 AND 16 (GROUP DU), ALL OF WHOM HAVE HAD SEVERE ATTACKS OF HOOKWORM DISEASE AND WERE NOT COMPLETELY CURED.

These two groups of children came from homes of approximately the same economic conditions. (See page 77 for explanation of terms used here.)

In Group Ds we find 12% coming from the best grade of homes, 59% from intermediate homes, and 29% from the poorest homes, while in Du we find 9% from the best homes, 64% from the intermediate, and 27% from the poorest homes. Group Ds averaged 11.1 years at the time of the second examination, whereas Group Du averaged 13.5 years. The Binet-Simon tests show that their average mental age is 8.9 years and 9.0 years, respectively. The fearful retardation indicated by these figures suggests at once that we are certainly dealing with defective children in Group Du and very likely so in Group Ds. Case No. 476—a girl of 13.1 years with a mental age of 6.6—is probably such a case. But our careful study made of these children did not reveal any other cause for the retardation than hookworm disease. There may be other causes present however. It is only fair, then, to remember that the two groups may differ not only in age but also in innate mental ability.

In Table XI are set forth the data we have obtained concerning these two groups of children. At the time of Examination II, Group Du excelled in all seven mental tests. But at the third examination they only excelled in two of these tests—the Form-Board and the Binet-Simon tests. There is no doubt whatever that the younger children here improved more during the 0.3 years than did the older children. From the "equal-group" method of comparison we obtain an average improvement of 5.9% for Group Ds and only 1.5% for Group Du. That is, the 13.5 year group have gained but one-fourth what the 11.1 year old children did. When the two groups are compared with the normal children (Group As) we see that the younger children have gained but 34% of what the healthy children accomplished, while the older children have gained but 9%.

Right here is probably the most important deduction from this whole study. *The longer the child has the hookworm disease the less will be the improvement mentally when the child is treated.* All of our knowledge of the physiology and psychology of growth and learning backs up this deduction. The time of growth is in the early years of life. The rate of growth is steadily decreasing from birth to maturity. A disease, such as hookworm disease, retards or entirely prevents normal development. The longer this continues the further back the child must start in the matter of development when he has been cured. And then the slower rate of improvement for that age prevents him from ever making up what he has lost. Suppose, for illustration, the rate of improvement in a mental trait at 10 years is 10%, at 11 it is 9%, at 12 it is 8%. A normal child starting with 100% would then gain 10% for the first year, making his ability 110%, then add 9% more the next year, or 119.9%, and 8% more the next year, or 129.5%. A child taken down with hookworm disease at his tenth year might gain, say, half of what his normal brother would (our figures suggest about 50–60%). If he was cured after two years he would present the following situations: 100% plus 5%, or 105%; then add 4.5%, or 109.7%, and then 8% if absolutely cured, or 118.5% at the end of the third year. He would then be 11% inferior to his normal brother (129.5% minus 118.5%) as the result of having had hookworm two years. And there is no indication from our data that this amount would be made up; rather that, because he is less capable by 11%, he will continue to drop behind to just that extent each year.

Conclusion.—The rate at which children who have severe cases of hookworm disease and who are not completely cured will improve in mental

TABLE XI

Comparison of Group Ds (10–12 Year Old Incompletely Cured Children) with Group Du (12–16 Year Old Incompletely Cured Children)

	Group Ds				Percent Gain (Equal Group Method)	Group Du				Percent Gain (Equal Group Method)
	Median and P. E.					Median and P. E.				
	Exam. II		Exam. III			Exam. II		Exam. III		
Opposites..........	1.90 secs.	*0.04*	1.47 secs.	*0.04*	*13.1%*	1.50 secs.	*0.08*	1.54 secs.	*0.07*	*7.7%*
Calculation.........	48.7 “	*5.0*	38.8 “	*6.2*	*12.5*	40.8 “	*17.0*	42.8 “	*5.3*	*5.4*
Logical Memory....	19.0 %	*2.3*	31.0 %	*2.4*	*18.1*	30.0 %	*2.6*	30.0 %	*2.3*	*0.6*
Memory Span......	6.0	*0.1*	5.9	*0.1*	*2.7*	6.0	*0.1*	5.8	*0.2*	*−3.5*
Handwriting.......	7.6 grade	*0.2*	7.4 grade	*0.2*	*−10.9*	8.3 grade	*0.5*	7.3 grade	*0.6*	*−9.0*
Form Board.......	20.0 secs.	*0.7*	18.4 secs.	*0.6*	*5.2*	18.2 secs.	*0.5*	15.8 secs.	*0.3*	*6.8*
Binet-Simon........	9.2 yrs.	*0.2*	9.7 yrs.	*0.3*	*5.4*	9.4 yrs.	*0.3*	9.8 yrs.	*0.2*	*2.5*
Averages..........	....		....		*5.9*	....		....		*1.5*
Ratios in terms of Group As (an average			of 17.6)..........		34	....		....		9

ability following treatment depends upon their age at the time of treatment—possibly rather upon the mental development they have reached than upon age alone. Children between the ages of 10 and 12 will improve very much more than will children between the ages of 12 and 16.

It seems undoubtedly true that these children will never reach in mental ability that degree of proficiency they might have had. Moreover, that the older children will never reach the ability that the younger children will attain. In other words, *the results all go to show that the longer the child has the disease the more handicapped he will be throughout life—that treatment will be of inestimable advantage to him, but that its value decreases rapidly in proportion to the length of time the child has been afflicted.*

SUMMARY OF THE RESULTS ON THE FOUR GROUPS OF CHILDREN FROM THE SEVEN MENTAL TESTS

Table XII presents a summary of the results from the seven mental tests. The per cent. of gain (or loss) of each group in each mental test is stated. An average of all these seven percents is likewise given. From this average it is apparent that the completely cured children (Group Cs) have gained but 60% of what the normal children gained, that the incompletely cured children have gained but 38%, and that

TABLE XII

Showing the Gain in Each of Seven Mental Tests for the Four Groups of Children

	As	Cs	Ds	Bs
Opposites	24.2%	3.0%	13.1%	2.9%
Calculation	27.0	20.5	12.5	25.5
Logical Memory	54.5	36.6	18.1	14.4
Memory Span	5.2	3.7	2.7	−6.5
Handwriting	1.2	1.6	−10.9	−9.8
Form-Board	9.3	5.8	5.2	9.0
Binet-Simon	2.0	2.3	5.4	5.6
Averages	17.6	10.5	6.6	5.9
Ratios	100	60	38	34

the non-treated hookworm children have gained but 34%. If we base our general average on but six tests, omitting the handwriting test, which is possibly the least significant, we have 59% gain for Group Cs, 47% for Group Ds, and 42% for Group Bs. Or, if we average the five middle ratings, thus omitting the two most widely divergent ratings of each group, we have 53% gain for Group Cs, 58% for Group Ds, and 38% for Group Bs. This gives an extreme variation in Group Cs from 53% to 60%, Group Ds from 38% to 58%, and in Group Bs from 34% to 42%.

In Table XIII is given similarly the totals from the seven tests, but here based on the children whose ages fall between 10.0 and 11.9, inclusive, instead of 9.9 to 12.0, inclusive. The then, the median of the boys being 7, 4 girls would equal or surpass this record. Now, if in a subsequent test the records should be:

Boys, 13, 12, 11, 10, 9, 8, 7, 6, and 5;
Girls, 11, 10, 9, 8, 7, 6, 5, 4, and 3,

then, the median of the boys being 9, we should find but 3 girls who equalled or surpassed this record. In the first test, 4/9, or 44%, of the girls equalled or surpassed the median of the boys, while in the second test but 3/9, or 33%, equalled or surpassed this record. The difference (11%) would indicate the extent to which the boys as a group were widening the gap between themselves and the girls.

Such data have been calculated for all the seven mental tests. They are presented in Table XIV. A similar set of data is presented in Table XV, but here the point from which measurements are figured is the −P. E. instead of the median. The median gives us the mid-point in point of performance of a group; the −P. E. gives us the point which divides the best three-quarters of a group from the poorest one-quarter of the group.

From Table XIV it is clear that Groups Cs, Ds, and Bs have not improved so fast as Group As—the normal children. Table XV tells the same tale. Averaging the results of these two tables we have Table XVI. To make these results clear, imagine that each group had 100 children in it, and that these 100 children were arranged in order of their ability. Then we should find 49 children in Group Cs superior to the ability shown by the 63rd child in Group As; we should find likewise 42 children in Group Ds superior to this child, and 47 children in Group Bs. The differences between 63 and 47, 42, and 47, respectively, indicate the effect of having hookworm disease upon Groups Cs, Ds, and Bs. About four months later only 41 of the children in Group Cs are now superior to the 63rd child in Group As. In other words, 8 children have lost enough in mental ability in Group Cs, because of having had hookworm disease and now being cured, to drop behind the 63rd child in Group As. Likewise in Group Ds, 11 children have dropped behind, and 11 children in Group Bs.

Table XVI, it is clear, substantiates the findings given in Table XII. Both show that the hookworm children have not developed as fast as the normal children. Both show that the completely cured children, who had severe cases, have developed faster than the incompletely cured children who had severe cases. Both show that the non-treated have not gained so fast as the normal children or the completely cured children—the latter group being about equal with them in physical and mental ability before the treatment. Both tables also show that the incompletely cured children over

TABLE XIV

Summary of the Mental Tests when the Data are Worked up According to Method III (see page 29). The Figures Indicate the Percent of the Children in the Several Groups that Equal or Surpass the Median Record of Group As.

	MEDIANS OF GROUP As		Group Cs			Group Ds			Group Bs			Group Du		
	Exam. II	Exam. III	II	III	Gain	II	III	Gain	II	III	Gain	II	III	Gain
Opposites	1.97 secs.	1.40 secs.	70%	26%	−44%	65%	26%	−39%	89%	17%	−72%	73%	45%	−28%
Calculation	38.2 secs.	28.7 “	22	15	− 7	29	18	−11	11	11	0	36	45	9
Logical Memory	31.5 %	52.5 %	52	26	−26	35	0	−35	44	11	−33	36	9	−27
Memory Span	6.3	6.3	38	39	1	34	36	2	40	31	− 9	31	27	− 4
Handwriting	9.2 grade	8.9 grade	26	37	11	24	12	−12	25	25	0	36	18	−18
Form-Board	16.1 secs.	14.3 secs.	15	7	− 8	6	13	7	33	22	−11	27	18	− 9
Binet-Simon	10.1 yrs.	10.3 yrs.	31	35	4	18	32	14	22	56	34	18	18	0
Average of seven tests			36	26	−10	30	20	−10	38	25	−13	37	26	−11

TABLE XV

Summary of the Mental Tests when the Data are Worked up According to Method III (see page 29). The Figures Indicate the Percent of the Children in the Several Groups that Equal or Surpass the —P. E. Record of Group As.

	P. E. of Group As		Group Cs			Group Ds			Group Bs			Group Du		
	Exam. II	Exam. III	II	III	Gain	II	III	Gain	II	III	Gain	II	III	Gain
Opposites	2.30 secs.	1.47 secs.	81%	41%	−40%	82%	50%	−31%	100%	33%	−67%	95%	45%	−50%
Calculation	52.3 "	38.4 "	59	59	0	56	47	− 9	22	33	11	64	45	−19
Logical Memory	23.0 %	37.0 %	74	63	−11	47	32	−15	56	44	−12	64	23	−41
Memory Span	5.7	5.8	58	60	2	66	60	− 6	60	53	− 7	69	50	−19
Handwriting	8.6 grade	7.9 grade	50	72	22	27	29	2	56	62	6	41	36	− 5
Form-Board	20.0 secs.	17.2 secs.	59	50	− 9	47	34	−13	44	33	−11	91	82	− 9
Binet-Simon	9.4 yrs.	9.8 yrs.	46	44	− 2	47	44	− 3	50	67	17	50	50	0
Averages of seven tests	....	....	61	56	− 5	53	42	−11	55	46	− 9	68	47	−21

TABLE XVI.—Summary of Tables XIV and XV

	Cs			Ds			Bs			Du		
	II	III	Gain	II	III	Gain	II	III	Gain	II	III	Gain
Averages of Seven Tests	49%	41%	− 8%	42%	31%	−11%	47%	36%	−11%	53%	37%	−16%

12 years have not gained so much as the incompletely cured children between the ages of 10 and 12. Table XII states these differences in terms of amount of improvement based on what normal children gain. Table XVI, on the other hand, states the differences in terms of how many children in 100 will fall behind their normal brothers and sisters in the race for mental supremacy.

Conclusion.—*Hookworm disease interferes very radically with mental development. Treatment alleviates this condition to some extent, but it does not, immediately at least, permit the child to gain as he would if he had not had the disease.* And when we take into account the results pointed out on page 80, we may add that our figures apparently show *the longer the child has the disease the more he will lose mentally and the less rapid will be his mental development after he has been treated.* It may, however, be pointed out that cases are known to hookworm specialists which are not, or seemingly are not, in harmony with this conclusion. Whether the lack of harmony is apparent or real remains to be determined.

PHYSICAL TESTS

The results of the physical examinations will be published by Stiles in another paper, but it is thought best to give the tapping test here as conducted by the psychologists and to summarize from Stiles' manuscript certain data on height, weight, grip and spirometer as applied to the restricted groups As, Bs, Cs and Ds.

In this section are presented results from the following tests:

(1) Weight.
(2) Height, standing and sitting.
(3) Grip, right and left hands.
(4) Spirometer.
(5) Tapping.
(6) Fatigue in tapping.

1. **Weight.**—The data are presented in Table XVII. Data based on the average, the median, or the "equal-group" method agree, with one exception, that the completely cured children gained most, the incompletely cured second, the normal children third, and the non-treated last. The one exception is in the case of the median, where the non-treated gained more than the normals.

Treating hookworm cases, then, results in an immediate gain in weight. And the gain is somewhat greater than normal children make in the same time, and considerably greater than untreated hookworm children make.

2. Height, both standing and sitting. — *Height standing.* The data are presented in Table XVIII. Those based on averages and the "equal-group" method indicate that Group Cs gained most, Group As next, Group Ds third, and Group Bs least. The data based on the medians place Group As last instead of second in amount of gain.

Height sitting. The data from the three methods of summarizing the groups are somewhat contradictory in Table XIX. Group Ds undoubtedly gained the most, Cs probably next, Bs third, and As least.

Combining the results from standing and sitting heights. In the following table are presented the average gains in the two tests according to the measures for each group:

	Group As	Group Cs	Group Ds	Group Bs
Averages..........	0.4 inch	1.15 inch	0.85 inch	0.55 inch
Medians...........	0.6	0.8	0.75	0.45
Equal Group......	0.75	0.85	0.75	0.7

It is very apparent that the treated children (Groups Cs and Ds) have gained more, regardless of the method of scoring, than have the

TABLE XVII

Weight. Expressed in Pounds and Decimals of a Pound

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group	16*				25†				17				7‡			
Average.......		73.2	76.8	3.6		63.5	67.9	4.4		63.4	67.6	4.2		70.9	73.7	2.8
Median.......		71.4	73.9	2.5		62.0	68.3	6.3		62.4	66.9	4.5		70.4	73.9	3.5
P. E. of Med..		*2.0*	*2.5*			*1.4*	*1.5*			*1.5*	*1.8*			*0.8*	*1.4*	
Sub-Groups																
M 120–110	1	111.6	113.9													
N 110–100	1	106.4	109.9													
O 100– 90	1	96.9	103.9													
P 90– 80					2	81.3	86.9		1	84.8	88.9		1	82.9	82.4	
Q 80– 70	6	73.8	77.3		3	72.7	78.2		3	72.5	78.0		3	73.1	77.0	
R 70– 60	4	61.7	65.3		10	65.9	70.6		7	63.5	67.4		2	67.4	71.1	
S 60– 50	3	55.5	58.5		9	55.6	59.3		6	55.3	59.0		1	59.5	60.4	
T 50– 40					1	46.4	48.9									
Aver. Q, R, S..	13	63.7	67.0		22	64.7	69.4		16	63.8	68.1		6	66.7	69.5	
Gain in % Q, R, S...........				*5.2%*				*7.2%*				*6.7%*				*4.2%*
Ratio in terms of As.......			100				138				129				81	

* Records from Cases Nos. 352 and 378 missing in Exam. III.
† Records from Cases Nos. 383 and 371 missing in Exam. III.
‡ Records from Cases Nos. 347 and 428 missing in Exam. III.

TABLE XVIII

Height, Standing. Expressed in Feet, Inches and Decimals of an Inch

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group	16*				25†				17				7‡			
Average.......		4- 6.7	4-7.4	0.7		4- 4.5	4- 5.4	0.9		4-4.6	4-5.3	0.7		4-6.4	4-6.9	0.5
Median.......		4- 7.5	4-8.2	0.7		4- 3.8	4- 5.3	1.5		4-4.5	4-5.6	1.1		4-6.5	4-7.3	0.8
P. E. of Med..		*0.6*	*0.6*			*0.4*	*0.5*			*0.4*	*0.5*			*0.4*	*0.4*	
Sub-Groups																
M 5′ 2″–4′11″	2	4-11.8	5-0.2		1	4-11.8	5- 0.0									
N 4′11″–4′ 8″	5	4- 8.7	4-9.3		2	4- 9.0	4-10.2									
O 4′ 8″–4′ 5″	4	4- 6.8	4-7.8		6	4- 6.5	4- 7.8		6	4-6.9	4-7.7		6	4-6.7	4-7.2	
P 4′ 5″–4′ 2″	3	4- 3.2	4-4.1		12	4- 3.4	4- 4.3		9	4-4.0	4-4.7		1	4-4.5	4-5.3	
Q 4′ 2″–3′11″	2	4- 1.9	4-2.7		4	4- 1.0	4- 1.9		2	4-0.3	4-0.9					
Aver. O, P....	7	4- 4.9	4-6.0	1.1	18	4- 5.0	4- 6.1	1.1	15	4-5.5	4-6.2	0.7	7	4-5.6	4-6.3	0.7
% Gain......				*2.1%*				*2.1%*				*1.3%*				*1.3%*
Ratio in terms of Group As.				100				100				62				62

* Records from Cases Nos. 352 and 378 missing in Exam. III.
† Records from Cases Nos. 383 and 371 missing in Exam. III.
‡ Records from Cases Nos. 347 and 428 missing in Exam. III.

TABLE XIX

Height, Sitting. Expressed in Feet, Inches and Decimals of an Inch

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group	16*				25†				17				7‡			
Average.......		2–3.3	2–3.8	0.5		2–2.7	2–3.4	0.7		2–3.1	2–3.9	0.8		2–4.1	2–4.5	0.4
Median.......		2–3.4	2–3.5	0.1		2–2.8	2–3.4	0.6		2–3.3	2–3.9	0.6		2–4.5	2–4.8	0.3
P. E. of Med..		*0.3*	*0.3*			*0.3*	*0.3*			*0.2*	*0.2*			*0.1*	*0.1*	
Sub-Groups																
M 2′ 9″–2′ 6″																
N 2′ 6″–2′ 3″	8	2–4.6	2–4.7		10	2–4.1	2–4.7		9	2–3.9	2–4.8		6	2–4.4	2–4.8	
O 2′ 3″–2′ 0″	8	2–2.1	2–2.9		15	2–1.9	2–2.5		8	2–2.2	2–3.0		1	2–2.3	2–3.3	
Average N, O..	16	2–3.4	2–3.8	0.4	25	2–3.0	2–3.6	0.6	17	2–3.1	2–3.9	0.8	7	2–3.4	2–4.1	0.7
% Gain.......				*1.5*				*2.2*				*3.0*				*2.6*
Ratio in terms of Group As.				100				147				200				173

* Records from Cases Nos. 352 and 378 missing in Exam. III.
† Records from Cases Nos. 383 and 371 missing in Exam. III.
‡ Records from Cases Nos. 347 and 428 missing in Exam. III.

normal children (Group As) or the non-treated children (Group Bs). The differences are, however, very slight. And likewise the differences between Groups Cs and Ds on the one hand and Groups As and Bs on the other are altogether too slight to be considered.

3. **Dynamometer test, right and left hand.**—Whether the data in Table XX, dealing with the results from the right hand, or Table XXI, dealing with the results from the left hand, are considered separately or together, we obtain no clear conception as to which groups have gained the most, barring Group As. This group has undoubtedly lost in comparison with the other three, especially in the left-hand test. With the exception of Group As, the changes between Examinations II and III are, then, not significant, as they are not greater than their probable errors. No reasons for the surprising loss of Group As can be given.

4. **Lung capacity, as measured by a dry spirometer.**—Complete agreement is shown between the results based on averages and on the "equal-group" method in Table XXII. Both show Group Cs to have gained the most, Group Ds second, Group As third, and Group Bs fourth. Data based on the medians indicate that Group Ds gained the most, Group Cs second, Group Bs third, and Group As a bad fourth. We shall accept the results given by

TABLE XX

Grip, Right Hand. Expressed in Kilograms on a Collin Dynamometer

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group	18				27				15*				9			
Average.......		14.5	14.0	−0.5		13.3	13.4	0.1		13.6	14.0	0.4		15.0	15.1	0.1
Median.......		14.8	14.0	−0.8		12.0	12.5	0.5		13.0	13.5	0.5		14.0	15.0	1.0
P. E. of Med..		*0.8*	*0.7*			*0.4*	*0.5*			*0.5*	*0.8*			*0.6*	*0.2*	
Sub-Groups																
M 25–21					1	24.0	22.0						1	21.0	20.0	
N 20–16	8	17.9	16.9		5	18.3	19.2		4	18.1	19.4		2	17.8	17.0	
O 15–11	7	12.9	12.9		15	12.7	12.5		10	12.1	12.2		6	13.1	13.6	
P 10– 6	3	9.3	9.0		6	8.9	11.5		1	10.0	11.0					
Average N, O..	15	15.4	14.9	−0.5	20	15.5	15.9	0.4	14	15.1	15.8	0.7	8	15.5	15.3	−0.2
% Gain.......				*−3.2*				*2.3*				*4.6*				*−1.0*

* Records from Cases Nos. 330 and 344 missing in Exam. III.

TABLE XXI

Grip, Left Hand. Expressed in Kilograms on a Collin Dynamometer

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group	18				27				15*				9			
Average.......		13.4	11.6	−1.8		12.1	11.4	−0.7		11.9	12.1	0.3		13.4	12.6	−0.8
Median.......		12.8	11.5	−1.3		11.0	11.0	0.0		12.0	11.0	−1.0		13.0	12.0	—1.0
P. E. of Med..		*0.7*	*0.5*			*0.5*	*0.4*			*0.4*	*0.4*			*0.8*	*1.1*	
Sub-Groups																
M 20–16	5	17.6	14.5		6	17.8	16.3		1	16.0	14.0		2	17.5	18.3	
N 15–11	9	12.7	10.8		10	12.3	11.0		11	12.5	12.7		6	12.7	11.1	
O 10– 6	4	9.5	9.9		11	8.9	9.2		3	8.8	9.3		1	10.0	11.0	
Aver. M, N, O.	18	13.3	11.7	−1.6	27	13.0	12.2	−0.8	15	12.4	12.0	−0.4	9	13.4	13.5	0.1
% Gain.......				*−12.0*				*−6.2*				*−3.2*				*0.7*

* Records from Cases Nos. 330 and 344 missing in Exam. III.

TABLE XXII

Lung Capacity. Expressed in Cubic Centimeters as Obtained by the Use of a Dry Spirometer

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group	18				27				17				9			
Average.......		1716	1969	253		1407	1760	353		1511	1821	310		1627	1867	240
Median.......		1747	1920	173		1430	1760	330		1470	1900	430		1620	1920	300
P. E. of Med..		*73*	*52*			*39*	*40*			*46*	*55*			*73*	*82*	
Sub-Groups																
M 2600–2301	2	2360	2680													
N 2300–2001	3	2080	2133										1	2080	2400	
O 2000–1701	5	1824	1984		4	1820	2000		5	1856	2064		3	1840	1947	
P 1700–1401	4	1540	1820		11	1527	1913		7	1497	1749		3	1547	1873	
Q 1400–1101	2	1280	1640		10	1224	1544		3	1333	1707		2	1200	1520	
R 1100– 801	2	1040	1600		2	880	1520		2	960	1640					
Av. O, P, Q, R.	13	1421	1761		27	1363	1744		17	1412	1790					
Aver. O, P, Q..	11	1548	1815		25	1524	1819		15	1562	1840		8	1529	1780	
% Gain O, P, Q, R........				*23.9*				*28.0*				*26.8*			(Estimated)	*22.0*
Ratio in terms of Group As.				100				117				112				92

the "equal-group" method as the most reliable expression of the situation, *i. e.*, that the completely cured children have shown the greatest gain (Cs, with 28% gain) and the incompletely cured next (Ds, with 27% gain), while the normal children (Group As, with 23% gain) and the non-treated children (Group Bs, with 22% gain) have shown the least gain.

5. **Tapping test. Speed of tapping 50 times, and fatigue from tapping 400 times.**—Casual observation has shown that the hookworm child gets out of breath very quickly and loses interest almost immediately in anything requiring physical exertion. For example, his grip in shaking hands is very weak to start with, but its characteristic peculiarity is the way in which the fingers relax after the first momentary attempt really to grasp one's hand. The tapping test was introduced into this study in the hope that it would throw some light on this very pronounced "fatigue" of the hookworm patient, and that it would thus differentiate very clearly between the normal and the hookworm child. The subject was required to tap with a sending-key, as fast as possible, 400 times. The time of executing each 50 taps, as recorded on an electric counter, was taken by the use of two stop-watches. A third watch recorded the total time. The latter was used solely as a check upon the eight separate times. The manipula-

tion of three stop-watches, together with watching the counter and recording the times can be done by any experimenter, but only after he has practiced the procedure until it becomes more or less automatic. Two records were taken with the right hand of each subject. The two records were separated in point of time by about 20 minutes, so that the second record was not injured by any fatigue lasting over from the first. It would have been better, however, not to have required the left-handed persons to tap with their right hand, as several of the records so obtained were very slow and not characteristic of right-handed children of that age and bodily condition. When the child came to make his second record he was urged in every possible way to make a fast one. His previous record was ordinarily compared with the records of his friends and he was stimulated to beat them. In most cases this second record was better than the first one, but in a few cases it was not. The better record was used, however, in every case. Careful study of the children who were tested showed very clearly that the tapping became painful to nearly all before the 400 taps had been made, and that the test involved not only physical fatigue but also that general mental attitude best expressed by the slang expression "grit." With very few exceptions the children did their best in both tests, and the records obtained are as accurate as can be obtained in such an experiment. This point should be emphasized, as there was really a very remarkable determination on the part of all but three or four cases to do their best.

It should be mentioned here that there was, of course, no uniformity in the way in which the children tapped. They were all given the same instructions and shown how to tap, holding on to the key with two fingers and thumb, using a free-arm movement, but nearly all varied this method as they tired. All sorts of combinations were thus actually employed. It was because the writer was so firmly convinced that the differences in tapping would be great enough to show up regardless of this factor that he used the test.

Three records from this experiment might be taken: (1) the initial speed, *i. e.*, the time necessary to tap the first 50 times; (2) the total efficiency, recorded as the average time taken in tapping each 50 of the 400 taps, and (3) the amount of fatigue, expressed as the difference in seconds between the first two records above. But as the data from the second can be readily obtained by adding the data from the first and third, it has not been presented here.

The measure of fatigue used here is a different one from that used elsewhere. It seems justified, and in fact seems better than preceding measures, in that it takes into account the total amount of slowing-up in tapping. As the usual tapping curve is shown by the line ABE in Plate I (based on the 24 subjects in Group Cs), it is apparent that a comparison of the speeds at A and C very much under-estimates the total slowing-up, for such a comparison implies the work curve shown by ACE. The measure used here gives appropriate credit to the subject, whether his work-curve takes the form of either one of the three lines shown in Plate I or, in fact, any other curve.*

This measure of fatigue has also the added advantage of being a measure in terms of amount of time and not of a ratio between initial and final performances. The latter is, among other objections, especially unfair to the subject who tries very hard at the start and has consequently a low initial rate. Even in those cases where such an individual loses no more actual time in his final rate, the fatigue

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* The index for fatigue as used by most investigators and recommended by Whipple ("Manual of Physical and Mental Tests," page 107), compares the record of the 1st 5 (or 10) sec. with that of the last 5 (or 10) sec. When such an index is used, the three curves ABE, ACE, and ADE would be shown to be equal in the amount of fatigue—manifestly unfair. Wells ("Studies in Retardation," *A. J. Psychol.*, XX, 1909, 38–59, etc.), in his study of retardation in manic-depressive insanity, compared the record of the first 5 sec. with the average of the second to sixth 5 secs. This method does not suffer from the above objection, as the writer found in his own study of retardation ("A Comparison Between Experimental Data and Clinical Results in Manic-Depressive Insanity," *A. J. Psychol.*, XXIV, 1913, 66–98).

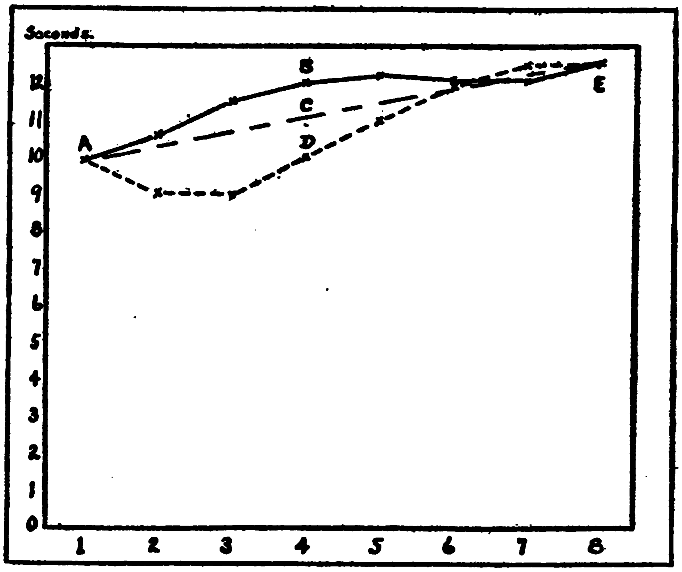

PLATE I. *Illustrating three possible work-curves in tapping.* Curve ABE is based on the records of 24 children in Group C, ACE is purely theoretical, while ADE is an approximate copy of a number of work curves obtained in this investigation. According to the prevailing methods of computing fatigue, the fatigue-indices would be equal in these three cases. Our method, expressed as the average amount of time consumed for each 50 taps over that shown by the time in tapping the first 50 taps (fatigue index $= \frac{\text{total time of tapping 400 times}}{8} -$ time of the first 50 taps), would assign to fatigue; 1.76 seconds per 50 taps for curve ABE, 1.40 seconds for curve ACE, and 0.86 seconds for ADE.

index for him is greater—a manifestly unfair measure.*

Any one familiar with hookworm patients would, I believe, declare that the hookworm children would not be able to tap as fast at the start as other children, that they would fatigue very much more quickly, and that their total records would accordingly be very much poorer than the controls. This appears to a slight extent in Table XXIII, where we find the controls tapping faster than the other three groups, but in Table XXIV, on the other hand, we find the incompletely cured (Group Ds) showing less fatigue than the normal children (Group As), and the completely cured (Group Cs) showing but a trifle more. At the time of Examination III the control squad was still tapping faster than the treated children, but not any faster than the non-treated, and it was showing greater fatigue than either Group Ds or Bs. There is, then, no particular evidence that hookworm disease interferes to any extent with the speed of tapping, either for a few taps or for as many as 400. This result seems most astonishing to the

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* For example, with the initial rate of 8 and final rate of 10, the fatigue index recommended by Whipple (*op. cit.*) is $\frac{10-8}{8}$, or 25%, while with an initial rate of 7 and final rate of 9 the fatigue index is 29%. Our fatigue measure, being expressed in terms of amount of time lost, would be equal in the two cases, providing, of course, that the work curve was of the same type. In this case, the average tapping time per 50 taps would be 9 and 8, respectively, and so the fatigue-measure would be 1 second in each case.

TABLE XXIII

Initial Speed of Tapping. Time Consumed in Tapping 50 Times.

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group	18				25†				17				9			
Medians......		8.8	8.7	0.1		9.7	9.2	0.5		9.2	9.3	−0.1		9.2	8.7	0.5
P. E. of Med..		*0.1*	*0.2*			*0.1*	*0.1*			*0.2*	*0.2*			*0.1*	*0.2*	
*Sub. Groups**																
M 8– 8.9	1	7.7	8.0													
N 9– 9.9	3	7.63	7.9		4	8.2	8.1		3	7.8	8.1		1	7.7	7.6	
O 10–10.9	6	8.77	8.6		3	8.77	8.77		6	8.95	8.7		3	8.93	8.23	
P 11–11.9	4	9.05	9.7		10	9.82	8.94		4	9.55	9.28		2	9.15	9.2	
Q 12–12.9	4	10.0	9.45		4	9.85	9.83		2	10.15	10.5		2	10.05	9.45	
R 13–13.9					2	11.35	10.05		2	13.0	10.45					
S 14–14.9													1	13.2	12.3	
T 15–15.9					1	12.0	9.7									
U 16–16.9																
V 17–17.9					1	14.3	?									
Av. N, O, P, Q.	17	8.86	8.91	0.05	21	9.16	8.91	0.25	15	9.11	9.15	−0.04	8	8.96	8.62	0.34
% Gain‡......				*0.5*				*2.3*				*−0.4*				*3.1*

* These sub-groups are arranged here on the basis of the *total* speed, not upon the basis of the initial speed.

† Cases Nos. 361 and 385 not tested in Exam. II.

‡ To make the two tables in Tapping comparable the percents. of gain are figured in terms of the averages from tapping 400 times, not 50 times.

TABLE XXIV

Fatigue in Tapping. Expressed as the Average Amount of Time (in seconds) Consumed for each 50 Taps Over and Above the Time Taken in Tapping the First 50 Taps

	Controls (As)				Completely Cured (Cs)				Incompletely Cured (Ds)				Non-Treated (Bs)			
	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain	No. of Cases	Exam. II	Exam. III	Gain
Entire Group	18				25†				17				9			
Medians......		1.8	1.9	−0.1		1.9	1.9	0		1.6	1.5	0.1		2.1	1.3	0.8
P. E. of Med..		*0.1*	*0.1*			*0.1*	*0.1*			*0.1*	*0.1*			*0.1*	*0.1*	
*Sub-Groups**																
M 8– 8.9	1	1.20	0.80													
N 9– 9.9	3	1.73	1.57		4	1.40	1.95		3	1.40	1.03		1	1.70	1.30	
O 10–10.9	6	1.57	1.80		3	1.90	1.83		6	1.50	1.33		3	1.40	1.40	
P 11–11.9	4	2.45	1.95		10	1.40	1.83		4	1.85	1.88		2	2.25	1.55	
Q 12–12.9	4	2.40	2.00		4	2.40	1.80		2	2.40	2.35		2	2.30	2.55	
R 13–13.9					2	2.00	2.60		2	.75	1.35					
S 14–14.9													1	1.50	1.30	
T 15–15.9					1	3.40	4.8									
U 16–16.9																
V 17–17.9					1	2.8	?									
Av. N, O, P, Q.	17	2.04	1.83	0.21	21	1.78	1.85	− .07	15	1.79	1.65	0.14	8	1.91	1.70	0.21
% Gain‡......				*1.9*				*−0.6*				*1.3*				*1.9*

* † ‡ See corresponding notes under Table XXIII.

writer, knowing, as he does, the physical condition of the children in the various groups.

But, of course, this must not be taken to mean that hookworm children do not fatigue easily. We know that they do from many varied observations. Evidently the test is not so well designed to measure muscular control and staying power as the writer had supposed.

It may be, indeed, that the ability to tap rapidly depends upon some lower, reflex center. As it happens, the fastest tapping rate in the writer's experience was made by a man addicted to smoking who stopped suddenly, and was consequently in a highly nervous state at the time of the test. Experiments upon manic-depressive patients have also led the writer to this same conception.*

There is no great difference in the gains made by the various groups between the two examinations. Our tables show that the non-treated (Group Bs) gained the most in speed of tapping (3.1%), the completely cured (Group Cs) were next (2.3%), the normal children (Group As) next (0.5%), and the incompletely cured (Group Ds) last, with a loss (−0.4%). Groups As and Bs showed the greatest gains in the matter of overcoming fatigue (1.9%), Group Ds next (1.3%), while Group Cs lost (0.6%). Putting the data together from the two tables, it would appear certain that the non-treated (Group

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* E. K. Strong, Jr., *op. cit.*

Bs) have made the greatest gain, the normal children (Group As) next, and the treated children least.

Conclusion.—The differences are very slight and cannot be relied on to any great extent. But to the extent that they represent true differences they show that the non-treated hookworm children have gained most, the controls next, and the treated children least (the completely cured gaining more than the incompletely cured). The gain of the controls over the treated children was due, not to a relative increase in initial speed, but to a better maintaining of that speed throughout the test. The results from the test must be considered very questionable, owing to the small differences between the groups.

Comparison Between the Children Between 10 and 12 Years of Age (Group Ds) and the Children Between 12 and 16 (Group Du), All of Whom Have Had Severe Attacks of Hookworm Disease and Were Not Completely Cured.

The general characteristics of these two groups have already been presented (page 80). It was there also pointed out that the younger group of children improved very much more mentally because of the treatment than did the older group. When we turn to consider this relative physical improvement we find a different situation. Table XXV presents the data. In this table are given the median improvements for each group before and after treatment. At the time of both examinations in all the tests (providing you combine the two tapping tests together) we find the older children superior to the younger. If the records of Groups Ds and Du are compared with the records of Group As (see Tables XVII to XXIV), we see that Group Ds is inferior to As in every test but the fatigue and "sitting height" tests at Examination II. Group Du, on the other hand, is inferior to Group As in only the weight, standing height, and spirometer tests in Examination II.

When it comes to the matter of expressing fairly the relative gains of these two groups, due to the treatment, we are confronted with considerable difficulty. If the six physical tests are averaged and their averages compared, it is evident from Table XXV that Group Du has improved more than Group Ds and that both have improved much more than Group As. If, however, the grip tests are eliminated, the tables are turned, and now Group Ds has gained more than Group Du and both groups have gained only approximately what Group As gained. We have already pointed out that the dynamometer test was very unsatisfactory, and it is therefore much more satisfactory to accept the results based on the five other physical tests than those based on all six tests, especially when by including the dynamometer test an entirely different condition is pictured. As has already been pointed out, the weight test, the height test, and the spirometer test are the only physical tests which showed any significant differences between the several groups. Data based on these three tests alone show that Group Ds gained a little more than Group Du, or in fact Group As, and that Group Du and Group As gained an equal amount.

Conclusion.—We would conclude, then, that hookworm disease has not interfered with the *physical development* of the older children as compared with the younger children to anything like the extent that it interfered with the mental development of the older children as compared with the younger children. And, correspondingly, the *rate of improvement* physically has not been interfered with to anything like the extent shown in the mental tests. The younger children have improved more than the older children, although the difference is slight. The older children have improved at the same rate as the normal children, while the younger children have improved at a slightly greater rate. Not much reliance can be placed on these last distinctions, however.

TABLE XXV

Comparison of Group D (10–12 Years Old, Incompletely Cured Children) with Group Du (12–16 Year Old, Incompletely Cured Children) in Physical Tests

	Group D					Group Du				
	Exam. II		Exam. III		Percent. Gain (Equal Group Method)	Exam. II		Exam. III		Percent. Gain (Equal Group Method)
	Med.	P. E.	Med.	P. E.		Med.	P. E.	Med.	P. E.	
1. Weight	62.4 lbs.	*1.5*	66.9 lbs.	*1.8*	*6.7*	68.9 lbs.	*2.4*	73.4 lbs.	*1.6*	*4.3%*
2. Height, standing	4′ 4.5″	*0.4*	4′ 5.6″	*0.5*	*1.3*	4′ 7.4″	*0.9*	4′ 8.2″	*0.9*	*1.7*
Height, sitting	2′ 3.3″	*0.2*	2′ 3.9″	*0.2*	*3.0*	2′ 3.9″	*0.4*	2′ 4.4″	*0.3*	*2.6*
3. Grip, right	13.0 kg.	*0.5*	13.5 kg.	*0.8*	*4.6*	17.0 kg.	*0.9*	19.0 kg.	*1.0*	*15.3*
Grip, left	12.0 kg.	*0.4*	11.0 kg.	*0.4*	*−3.2*	16.0 kg.	*0.8*	17.0 kg.	*0.6*	*7.1*
4. Spirometer	1470 c.c.	*46*	1900 c.c.	*55*	*26.8*	1733 c.c.	*79*	2053 c.c.	*103*	*25.0*
5. Tapping, speed of	9.2 secs.	*0.2*	9.3 secs.	*0.2*	*−0.4*	8.8 secs.	*0.3*	8.7 secs.	*0.4*	*−3.3*
6. Fatigue in tapping	1.6 secs.	*0.1*	1.5 secs.	*0.1*	*1.3*	1.8 secs.	*0.2*	1.7 secs.	*0.2*	*3.7*
Average of 6 tests					*6.2*					*7.2*
Ratio of improvement in terms of Group As					147					167
Average of 5 tests, omitting Grip					*7.3*					*6.4*
Ratio of improvement in terms of Group As					109					96
Average of weight, height and spirometer					*11.9*					*10.5*
Ratio of improvement in terms of Group As					116					102

SUMMARY OF THE RESULTS FROM THE PHYSICAL TESTS.

Several of these tests show that hookworm disease interferes with the physical development of the child. They show that the control squad is about 10 pounds heavier and 2 inches taller than the treated children, but only 2.3 pounds heavier and 0.3 inch taller than non-treated. The grip of the normal children is also about 2½ pounds stronger than the treated children, although no stronger than Group Bs. Their lung capacity appears to be markedly superior to the other groups at the time of the second examination, but it is no greater than that of Groups Ds and Bs at the time of the third examination. No characteristic differences have been found concerning speed of tapping or fatigue in tapping.

Evidently the children comprising our non-treated hookworm group have not suffered very much from their disease. The same inference can be drawn from a study of the mental tests. They do not represent such severe attacks of the disease, or at least attacks continuing over such a long period of time, as are to be found in Groups Cs and Ds. This fact must be constantly borne in mind in comparing the four groups. Groups Cs and Ds have really suffered mentally and physically from the disease, whereas Group Bs has not suffered very much. Conse-

TABLE XXVI

Showing the Gain in Each of Six Physical Tests for the Four Groups of Children

	As	Cs	Ds	Bs
1. Weight	*5.2%*	*7.2%*	*6.7%*	*4.2%*
2. Height, standing	*1.8*	*2.2*	*2.2*	*2.0*
Height, sitting				
3. Grip, right hand	*−7.6*	*−2.0*	*0.7*	*−0.2*
Grip, left hand				
4. Spirometer	*23.9*	*28.0*	*26.8*	*22.0*
5. Tapping, speed of	*0.5*	*2.3*	*−0.4*	*3.1*
6. Fatigue in tapping	*1.9*	*−0.6*	*1.3*	*1.9*
Average of 6 tests	*4.3*	*6.2*	*6.2*	*5.5*
Ratio of gain in terms of Group As	100	144	144	128
Average of 5 tests, omitting grip	*6.7*	*7.8*	*7.3*	*6.6*
Ratio of gain in terms of Group As	100	116	109	99
Average of weight, height and spirometer	*10.3*	*12.5*	*11.9*	*9.4*
Ratio of gain in terms of Group As	100	121	116	91

quently, we should not expect to find any marked difference between Groups As and Bs. That we find such an overwhelming superiority in the gain of As over Bs in the mental tests is, then, all the more significant.

We have now considered the actual differences in some physical traits between the various groups at the time of the second examination. Let us now turn and consider what difference in amount of improvement there exists between the four groups. This information is gathered together in Table XXVI. Summaries are presented here, as in Table XXV, based (1) on all six physical tests, (2) on five tests, omitting the dynamometer test, and (3) on the three tests—weight, height, and spirometer. We believe that the data from the dynamometer test is influenced by some unknown extraneous cause which deprives it of significance.* Consequently the last two summaries are alone referred to. From the figures we may conclude that the two treated groups gained in physical traits a little more than normal children, and that the non-treated gained at the same rate (or possibly a little less) as normal children. The differences between all four groups are, we should judge, not in excess of their probable errors.

In Tables XXVII, XXVIII and XXIX are presented a summary of the results from the physical tests as calculated by our Method III (see pages 29 and 87). Actually three summaries are presented, based (1) on an average of all six physical tests, (2) on five physical tests, omitting the dynamometer test, and (3) on an average of the weight, height, and spirometer tests alone. The first two summaries bring us to identically the same conclusion, *i. e.*, that Groups Cs and Ds and Bs have all developed faster physically than the normal children, and that all three groups have gained at practically the same rate. Inspection of Tables XXVII and XXVIII show, however, that this development of non-treated (Group Bs) is largely to be attributed to a phenomenal showing in the tapping and fatigue tests. Consequently, in the third summary, based only on the weight, height, and spirometer tests, we find that Group Bs has gained at the same rate as the normal children (actually –1%). Barring this exception, this summary agrees with the other two summaries in indicating a larger gain for the treated children (Groups Cs and Ds) than the normal children (Group As). As for Group Du, it is clear that this group has simply gained at the same rate as the normal children. The 10–12-year-old children of Group Ds have, then, developed at a greater rate than the 12–16-year-old children of Group Du.

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* One dynamometer was broken at the close of Examination II and another was used during Examination III. At the time there was no evidence that these factors would affect our data and it is not yet clear how they could affect them.

Conclusion.—Our data show that the treated hookworm children (Groups Cs and Ds) are considerably inferior physically to normal children. They also show that in the interval between the two examinations the treated hookworm children have developed a trifle faster than the normal children. It is a fair question to ask, as we did in discussing the mental tests, whether these treated hookworm children will ever gain the physical condition they might have had if they had never been sick. Here undoubtedly the results present a far more favorable future than did the data based on the mental tests. And when the conclusions based on the more purely physiological tests are borne in mind one is very

TABLE XXVII

Summary of the Physical Tests when the Data are Worked up According to Method III (see page 29). The figures Indicate the Per Cent of the Children in the Several Groups that Equal or Surpass the Median Record of Group As

	Median of Group As Exam. II	Median of Group As Exam. III	Group Cs II	Group Cs III	Group Cs Gain	Group Ds II	Group Ds III	Group Ds Gain	Group Bs II	Group Bs III	Group Bs Gain	Group Du II	Group Du III	Group Du Gain
Weight	71.4 lbs.	73.9 lbs.	16	24	8	18	26	8	43	50	7	45	45	0
Height, standing and sitting	3′ 5.5″	3′ 5.8″	26	34	8	30	39	9	50	43	−7	58	65	7
Grip, right and left hands	13.8 kg.	12.8 kg.	35	37	2	34	45	11	56	64	8	73	75	2
Spirometer	1747 cc.	1920 cc	15	31	16	29	47	18	44	50	6	55	59	4
Tapping	8.8 sec.	8.7 sec.	20	32	12	29	32	3	22	50	28	45	41	−4
Fatigue in tapping	1.8 sec.	1.9 sec.	46	50	4	65	68	3	44	89	45	50	64	14
Average			26	35	9	34	43	9	43	58	15	54	58	4
Average, omitting grip			25	34	9	34	42	8	41	56	15	51	55	4
Average, weight, height and spirometer			19	30	11	26	37	11	46	48	2	53	56	3

TABLE XXVIII

Summary of the Physical Tests when the Data are Worked up According to Method III (see page 29). The Figures Indicate the Percent. of the Children in the Several Groups that Equal or Surpass the —P. E. Records of Group As

	—P. E. Records of Group As		Group Cs			Group Ds			Group Bs			Group Du		
	Exam. II	Exam. III	II	III	Gain	II	III	Gain	II	III	Gain	II	III	Gain
Weight	60.6 lbs.	61.6 lbs.	58	64	6	59	76	17	86	86	0	82	82	0
Height, standing and sitting	3′ 2.9″	3′ 3.8″	54	54	0	74	74	0	100	100	0	90	95	5
Grip, right and left hand	11.0 kg.	10.0 kg.	62	72	10	70	79	9	83	89	6	82	89	7
Spirometer	1440 cc.	1680 cc.	48	61	13	59	65	6	72	61	−11	68	64	−4
Tapping	9.3 sec.	9.5 sec	32	68	36	59	62	3	56	78	22	64	73	9
Fatigue in tapping	2.4 sec.	2.1 sec.	74	66	−8	94	88	−6	83	89	6	82	69	−13
Average			55	64	9	69	74	5	80	84	4	78	79	1
Average, omitting Grip			53	63	10	69	73	4	79	83	4	77	77	0
Average, weight, height and spirometer			53	60	7	64	72	8	86	82	−4	80	80	0

TABLE XXIX

Summary of Tables XXVII and XXVIII

	Group Cs			Group Ds			Group Bs			Group Du		
	II	III	Gain	II	III	Gain	II	III	Gain	II	III	Gain
Average of 6 physical tests	41	50	9	52	59	7	62	71	9	66	69	3
Average of 5 tests, omitting Grip	39	49	10	52	58	6	60	70	10	64	66	2
Average weight, height and Spirometer	36	45	9	45	55	10	66	65	−1	67	68	1

much tempted to answer the question in the affirmative. The fact that the differences in Tables XXVI and XXIX are so small prevents a definite answer from the data presented there. The tables do point out that treating hookworm children brings about a greater physical development than would appear if they were not treated. And when Table XXV is taken into account it is made clear that the older the child at the time of the treatment the less chance there is of that child gaining the physical development he might have had.

Hookworm disease interferes with physical development. Treatment alleviates this condition to a considerable extent without a doubt. Whether it will enable a child to reach the physical development it might have had cannot be answered. The writer's opinion is that the child will gain a great deal, but not all. The data do point out that *the older the child when treated—meaning, of course, the longer the child has had the disease—the less likely it is that he will ever reach his normal physical development.*

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